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Chas. F. McKenna

Tech
Chemical Engineering Progress

TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

CHEMICAL ENGINEERS

VOLUME II

1909

OFFICE OF THE SECRETARY
POLYTECHNIC INSTITUTE
BROOKLYN, N. Y.

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CONTENTS

	PAGE
First Semi-Annual Meeting	1
Resolutions on the Death of Dr. H. August Hunicke	5
Report of Membership Committee	6
Treasurer's Report	7
Business Session	8
Excursions	13
Second Annual Meeting	15
Report of Membership Committee	18
Proposed Amendment to Constitution	19
Treasurer's Report	24
Report of the Committee on Chemical Engineering Education	24
Business Session	27
Excursions	45
Dinner	47
Constitution	49
By-Laws	54
Officers and Committees for 1910	55
List of Members	57

ADDRESSES AND PAPERS READ BEFORE THE INSTITUTE

		PAGE
The Centering of Great Industries in the New York Metropolitan District	CHAS. F. MCKENNA,	65
Chemical Industries of America	Prof. CHAS. E. MUNROE,	84
Conservation and the Chemical Engineer	SAMUEL P. SADTLER,	105
Efficiency Limits in the Power-Gas Producer.	Prof. WM. D. ENNIS,	115
The Utilization of Low-Grade Fuels in the United States	O. K. ZWINGENBERGER,	140
Heat Efficiency of Smokeless Combustion and Heat-Absorbing Capacity of Boilers	A. BEMENT,	156
Chemical Composition of Illinois Coal and the Relation of Heating Value to Composition.	A. BEMENT,	175
Creosote Oil from Water-Gas Tar	SAMUEL P. SADTLER,	177
Some Experiments on the Case Hardening of Steel by Gases	JOHN C. OLSEN, JOHN S. WEIFFENBACK, and JOHN R. BRIERLY,	194
An Automatic Acid Egg	R. K. MEADE,	201
A Method of Clay Control for the Manufacture of Cement.	JOHN G. DEAN,	204
Colloids and the Ultramicroscope	JEROME ALEXANDER,	210
The Utilization of Waste India Rubber	STEPHEN P. SHARPLES,	229
On the Permanance and Acidity of Hydrogen Peroxide Solution	LAUNCELOT W. ANDREWS,	238
Commerical Extraction of Grease and Oils	WILLIAM M. BOOTH,	248
Glycerine Refining in Multiple-Effect Stills	F. J. WOOD,	261
The Advantages of the Multiple-Effect Distillation of Glycerine and other Products	A. C. LANGMUIR,	274
Electric Furnace for the Smelting of Iron Ore.	EDWARD R. TAYLOR,	280
Waterways and Water Power	EDWARD R. TAYLOR,	300

TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

FIRST SEMI-ANNUAL MEETING

HELD AT THE POLYTECHNIC INSTITUTE, BROOKLYN, N. Y., JUNE 24 TO 26, 1909

Pres. Sadtler:

The program which we have before us calls first for an address of welcome from Comptroller Herman A. Metz.

Mr. Metz:

Mr. President, Gentlemen: I was asked to extend to you a welcome to New York. I know of only one hotter place than this, and I am glad that I am in New York, hot as it is, and I hope that you will feel the same before you get through.

It is a great satisfaction to have you here—for such societies as yours to come together here for conventions and other purposes. I regret that from a business point of view we have not more to offer in the way of locations for plants. The policy of the city seems to have been to drive them out, and they have gone to sister cities. I think you will find that our natural opportunities are such that we ought to have in certain sections of this city large manufacturing establishments. The conveniences offered to a manufacturing establishment in being located in a metropolitan district is apparent; help can be more readily obtained here than in rural districts; but you probably know more about your own business than I do (although I am continually reminded that other people know more about my business than I do myself).

I wish to extend to you a welcome to New York—to our plants and to our city. It is usual for whoever takes a stranger to show

him the town to say, "You probably know more about it than I do." You will find much to interest you here in this, the grandest city on the face of the earth, and in Brooklyn, one of its best boroughs (although it would not appear so from what we read in the newspapers). I hope that you will enjoy your stay here, and that your discussions will be of great value, as an exchange of opinions and experiences must be at all times, and I trust you will find that you have made no mistake in coming to this town.

Prof. Irving W. Fay:

Mr. President and Members of the American Institute of Chemical Engineers: The Polytechnic Institute is glad to welcome you, and to put its hall and buildings at your disposal during this session. The Institute has attempted, and it has, I believe, succeeded, in graduating men who have a good conception of the professional career which is before them. As is it an honest one and a serious one, there must be a standard set, and met, and if I understand the *raison d'être* of your Institute, it is the elevation of a higher standard among chemists and chemical engineers in this country.

I do not think it has come a moment too soon. The Institute was formed immediately succeeding a period of panic—a good time for its formation. Business is now on the upward curve; better times are ahead, and there is a demand for more and higher-class men. The need of the country in this respect is apparent to anyone who knows the kind of men who have worked and done business under the name of chemist in the past. They remind me of an old lady who was attending a meeting in the early history of the country when Unitarianism was first projected. Everyone was pouring anathemas upon Unitarianism because of the absence of the theories of damnation from its creed. After everyone had had his say, this dear old lady got up and approved of all that had been said, and hoped that the doctrine of damnation would not be left out, because, she said, "my damnation is very dear to me." So I think some men have taken the name of chemist and held it dear out of veneration for the name.

The influence of your Institute can do a great deal for the excellence, skill and power of the chemical engineer in this country. I care not how great a panic there may be in England about building Dreadnoughts to fight Germany, the outcome of the struggles

to be fought in the future will depend first on the natural richness of the country in which the people live, and after that it will depend upon the endowment of brains, and the training, with which the people are equipped. Your Institute has the high privilege of setting the standard, so that all men shall know the standard, and when it is met. Every science must be standardized, and every standard must be high, and then comes progress, and the fruits cannot be located in any Institute; they will go to the humblest laborer who has a hand in producing anything that is produced in a better way because of it. I welcome you to the Polytechnic Institute, and extend to you the invitation to visit its laboratories.

Pres. Sadtler:

On behalf of the visiting members of the Institute, I wish to thank very much the gentlemen who have welcomed us, and to say that we appreciate their welcome. This idea of coming to Brooklyn is a welcome change from attending, as we have done formerly, the various meetings in New York. The idea of having a meeting over here was a very agreeable surprise to me, and is, undoubtedly, a great pleasure to all of us. My earliest impressions of Brooklyn were in connection with a visit to the chemical works of Dr. Squibb, and therefore in connection with chemical industry. I have no doubt that we shall learn very much in the course of the inspection of many of these industries of Brooklyn and New York. There is hardly a section of this great district but what is important from a chemical standpoint. We have before us a very modest program, and ours is a very modest and young society. We have had to stand a little bit of ridicule because we are such a small society in comparison with the great organizations, but we do not propose to be a society that is starting in with a view to building up numbers—we are not following the same lines as some of the big societies. I think you will probably find that there is room for this kind of a society. Most of us who belong to this organization belong also to other societies. Over and above that I think it will be evident after another meeting or two that there is room for a society of chemical engineers to come together to discuss the problems of applied chemistry, make acquaintances, and visit works in which the applications of chemistry are being carried out. We shall learn more in that way than

in a year of reading about that kind of thing. I hope that our expectations will be realized in the papers of to-day and the excursions of the next few days. I will not take more of your time. First of all we have Secretary Olsen's announcements, and then we will go on with the program.

Secretary Olsen then outlined the plans for the entertainment of the members during the meeting, and gave instructions how to reach the various places to be visited. He also announced that a little before noon Mr. Jerome Alexander would exhibit and explain the ultramicroscope, and that after seeing the instrument there would be a number of young men ready to show members through the Institute buildings. At twelve o'clock the Institute as a body would pass out to the front of the building and have a photograph taken, as the papers wished to publish in their to-morrow's issue a photograph of the members of the Institute.

Pres. Sadtler:

We are ready now to hear the papers. Three papers are on the program for this morning.

The following papers were then read:

"Limits of Efficiency of the Power Gas Producer," by Prof. W. D. Ennis, of the Polytechnic Institute, Brooklyn, N. Y.

"The Utilization of Low-grade Fuels in the United States," by O. K. Zwingenberger, of New York, N. Y.

"Creosote Oil from Water Gas Tar," by President S. P. Sadtler of Philadelphia, Pa.

After the reading of the papers Pres. Sadtler suggested that discussion be deferred until the afternoon session, as time was passing rapidly, and the photographers were waiting, and members wished to see the ultra-microscope.

12 A.M. A business meeting of the members was then called.

Pres. Sadtler:

I would first of all present the Institute with a statement with regard to the decease of one of the Vice Presidents of the Institute, Dr. H. A. Hunicke of St. Louis, which Dr. Frerichs has prepared, and which I will read for the edification of the Institute.

The following resolution was then read and unanimously adopted by a rising vote:

H. Aug. Hunicke

RESOLUTIONS ON THE DEATH OF DR. H. AUGUST HUNICKE

"Dr. H. August Hunicke has been taken from us by an unexpected death and the A. I. Ch. E. has lost in him a most valuable member and faithful officer. He was a man of high culture and possessed thorough knowledge in his profession. His sterling character, combined with a keen sense of honor, compelled him always to put professional honor above material gain.

"Therefore he felt particularly attracted by the aims which the founders of the A. I. Ch. E., set for themselves in their constitution. He became an enthusiastic member and devoted a valuable part of his time to the organization and development of the Institute.

"His unfailing kindness of disposition has won many friends for him among our members during the short time of their acquaintance with him, and all of us sincerely deplore his premature death.

"Be it therefore resolved, That this be enacted in the records of the A. I. Ch. E., that a copy of these resolutions be sent to his family and that the members of the Institute, in semi-annual convention assembled adopt these resolutions by rising from their seats to honor the memory of our departed Vice President."

The above resolutions were offered by Dr. F. W. Frerichs. In seconding these resolutions, Dr. Charles F. McKenna spoke as follows: "It would not be out of place for one to add a word to Dr. Frerichs' pathetic tribute to Dr. Hunicke. There have been few times in my life when but a single occasion of meeting another has been sufficient to develop towards him feelings of high regard and admiration, but my first, and sad to say, my last meeting with Dr. Hunicke was one of these. Perhaps I had been prepared a little for such an effect, because I had been previously told by one of his own admiring fellow citizens, when I mentioned Dr. Hunicke, that there was one who was a scholar, an honorable man and a gentle soul. These were exactly the attributes which most impressed those of our members who met him for the first time at Pittsburg. We will miss him now, but we are left a legacy of inspiration and an addition to the store of valuable aspirations which marked the first hours of our Institute's existence. The work he did then for this cause will endure, the principles he stood for then will be cherished, and in the results will always be found a fit tribute to his memory."

After reading Dr. Frerichs' statement President Sadtler called upon Secretary Olsen for the report of the Membership Committee.

Report of the Membership Committee

Four meetings have been held since the annual meeting at Pittsburg. Four Institute ballots have been canvassed by the Committee. The number of ballots cast have been 50, 61, 67, and 63. Twenty-four men were declared elected in that time, bringing the membership up to 100. Three men received enough negative votes to reject them, which makes 12.5 per cent rejections out of the candidates recommended to date. Twenty-six applications were considered; 19 were recommended for election; 2 were under age, and these applications were held over until they became of age; 4 had had insufficient experience in chemical engineering work; 1 was rejected because his technical career did not entitle him to membership.

A design for a button was ordered made, and tentatively adopted, for the use of the members at this meeting.

An engrossed form of certificate of membership was considered, but no action was taken.

The committee recommended that members should be more active in inviting men who are qualified to apply for membership.

Pres. Sadtler:

Are there any comments on matters brought out in this report? I would merely say with regard to the last recommendation from the Membership Committee that this Institute cannot solicit membership as some other institutions do. The American Chemical Society and the American Electrical Society both solicit membership. They are large organizations and anybody interested in their lines of activity is welcome to join. This makes it the more incumbent upon the members who desire a strong, vigorous organization to look around among their circle of friends, and see if they cannot pick out men who, in their opinion, are thoroughly suitable to become members of this Institute. This organization is something like a club, in that the Committee on Membership carefully scans qualifications. At times there may be some dissatisfaction felt with the activity or work of this Committee, but I think that, on the whole, it has been productive of good in the

careful scanning of qualifications, so that we do not get any men who merely want to belong to a new organization. I hope that in the future the admission to membership will be made as carefully as in the past. The Society has a certain standard, and its obligations will become more numerous, so that it will have to take care in passing upon qualifications.

The report of the Treasurer was then read:

Treasurer's Report

From July 1, 1908, to July 1, 1909.

Receipts

Received from members	$1089.86
Interest	0.16
Total	$1000.02

Expenses

Exchange	$ 6.05	
Organization expenses to July 1, 1908	210.52	
Secretary, 1909	162.19	
Treasurer	8.00	
Printing	137.09	
Rooms	24.00	
Pittsburg meeting	35.00	
Stenographer	3.50	
Humidity chart for Dr. Grosvenor's paper, May 26th	20.00	
Total expense	$606.35	606.35
Balance July 1, 1909		$483.67

William M. Booth,
Treasurer.

J. C. Olsen:

If is it in order I would like to move a vote of thanks to Professor Ennis, who gave us the paper on the efficiency of the power-gas producer. He is not a member, and I therefore move that he be given the thanks of the Institute for giving us such an excellent paper as he did.

The motion was seconded and passed.

Meeting adjourned until two o'clock.

The afternoon session was called to order at 2 o'clock, and the following papers read and discussed:

"Some Experiments on Case Hardening of Steel with Gases," by J. C. Olsen, of Brooklyn, N. Y.

"Automatic Acid Egg," by Richard K. Meade, of Allentown, Pa.

"The Centering of Great Industries in the New York Metropolitan District," by Chas. F. McKenna, of New York.

"Methods of Clay Control," by J. G. Dean, of Exshaw, Alberta, Canada.

WM. M. GROSVENOR:

If this time be suitable, permit me to offer a resolution in recognition of our cordial welcome by Comptroller Metz, and to express our thanks to the Polytechnic Institute for their hospitality; also to extend thanks to the National Lead Co., Corn Products Refining Co., Warner Sugar Refining Co., the Standard Oil Co., the Consolidated Gas Co., and the officers in charge of the Brooklyn Navy Yard for their invitations, for the opportunity to inspect the new Manhattan Bridge, and to Mr. McAdoo, for the permission to visit the new Hudson tunnels.

The motion was seconded and carried.

C. F. MCKENNA:

If you have ten or fifteen minutes to give to other business, I wish to express an opinion about our next meeting. It seems to me that we ought not to adjourn our regular business and executive session without coming to some understanding about the place, and perhaps the character of our next annual meeting. This meeting has developed into such a success and we have seen so many important subjects like that of wood preservation develop and call for discussion which had to be abridged, and feeling that there are scores of such topics that might perhaps develop at our annual meeting, I think a longer period should be provided for reading and discussion (although I heard one very excellent member say that he did not give a hang about papers—what he wanted was excursions). What is the consensus of opinion as to the proposition to hold the annual meeting at a Southern city, or a Middle Western city like St. Louis?

Pres. SADTLER:

This is a very important topic, gentlemen. You must remember that the early winter meeting will be the annual meeting, at which we will have to elect a complete new set of officers, the present officers not being eligible for re-election. It is also necessary to settle the date of the meeting. It is very unfortunate that we have twice had a conflict with the American Chemical Society. The American Chemical Society held their meeting in Baltimore just a few days after our Pittsburg meeting. Some gentlemen do not want to take in both meetings. Some hurried away from our meeting, after staying only one day. The Detroit meeting of the American Chemical Society takes place early next week. We have preceded them by a few days. It is very desirable to choose a date for our December meeting that will be distinctly apart. It will be convenient, possibly, to have a meeting quite early in the month of December. The other meetings are always held, if I remember rightly, during the so-called "holiday week." Then we can have a meeting which will stand on its own merits. And we can have a good gathering of everybody interested in our lines of study.

C. F. MCKENNA:

I move that the Committee on Meetings be instructed to settle the dates of the next annual meeting between the 1st and 10th days of December.

Pres. SADTLER:

The motion is before you. Is there anything to be said on that? How would it suit the members who are here to meet between the 1st and 10th of December? That is not a time, I suppose, that would interfere with anyone very much.

J. C. OLSEN:

It seems to me that ten days is a very limited time. It had better be between the 1st and 15th. That will give us a little more leeway. We have to look out for Sundays and holidays, and it seems to me that it would be better to make it fifteen days.

C. F. MCKENNA:

Amendment accepted.

Pres. Sadtler:

You have the amended motion before you that the Committee on Meetings be instructed to select a date for the annual meeting between the 1st and 15th of December.

Motion carried.

Pres. Sadtler:

Now with reference to the place of meeting. It would be well, perhaps, to make some suggestions with regard to that. I think St. Louis should be considered very favorably, because we have a strong membership there. I think we have ten or a dozen members in St. Louis—men prominent in the chemical industries there, and I think they would organize a very nice local interest for us, and at all events it would be a very important thing to recognize something of that kind. Of course there are other important cities; we have held only two meetings—one at Pittsburg, and the other at New York.

Wm. M. Booth:

I move that the next meeting be held at St. Louis.

Pres. Sadtler:

I would suggest that we do not settle upon the matter arbitrarily, because it will really have to be done after consulting the St. Louis members. But if they are in favor of the plan, and desire a meeting there, I think an expression of a desire to hold the meeting there would be in order.

S. F. Peckham.

I think the point just made is well taken—to consult the St. Louis members.

Pres. Sadtler:

Is it understood that those present express themselves as favorable to the choice of St. Louis to the Committee on Meetings if that Committee finds everything satisfactory?

J. C. Olsen:

It seems to me, Mr. President, although there are, I think, about ten members in the vicinity of St. Louis, the greatest number would be served by the choice of Philadelphia. We were as far west as Pittsburg last time, and we had a very good attend-

ance of St. Louis members there. More than thirty-five of our members live in the vicinity of New York and Philadelphia, and we can consider that New York and Philadelphia together possibly have about half the membership. The eastern part of Pennsylvania is very close, and there are a great many chemical works there. I think we would get a larger number of members present at a meeting in Philadelphia than in St. Louis.

C. F. McKenna:

I think that the Committee on Meetings should be encouraged to get a larger number of papers of the character of the most promising type to-day, such as that on wood treatment, and the industries generally, so as to bring out a full discussion of everyday facts.

Pres. Sadtler:

I would suggest that it would be a very good thing for the Committee on Meetings to send a circular, mentioning two or three places like Philadelphia or St. Louis, and ask for an informal vote of the whole membership. If we can get the whole membership to express themselves on two or three proposals of that kind, we can come to a knowledge of what we want.

It is suggested then that the matter be left in the hands of the Committee on Meetings.

Wm. M. Booth:

I found this year in visiting the west that Chicago and St. Louis are eastern points. We have a number of men on the other side of the dividing line. It occurs to me that as this is a national organization, St. Louis would be a central point, and we ought not to be selfish and ask men to come all the way east. For instance, we have members in Omaha, in California, and a number in and about Chicago. We ought to consider their convenience and wishes.

Pres. Sadtler:

I would like to say that personally I would be very much pleased to have the meeting in Philadelphia, because then I would not have to make an extensive trip. But I am not so local in feelings as Secretary Olsen. I know that this is a very big country. We cannot have a national association and be clannish about it.

The western men will be apt to say, "What are we paying $15 a year for? If we have to pay a lot to travel to Philadelphia, we get nothing out of it!" Let us remember that this is a big country, and that a great portion of it is west of the Mississippi River. I should be very pleased not to take an extensive trip, but at the same time I am quite prepared to take a trip somewhere west of the Mississippi.

Wm. M. Booth:

There are a great many men in the west who are very much interested in this movement. If we can interest them a little more, we are going to get some members who are interested in the mining side of chemistry. If we hold a meeting in Chicago or St. Louis, it might attract those men from that section of the country.

Member:

The people who live west of the Alleghenies are more accustomed to coming east than those who live east are accustomed to going west.

Pres. Sadtler:

This Society, of course, will prosper, and we will be able to do things that have some real interest to members, and we will be able to make our membership valuable, if we increase our numbers moderately. I do not think we ought to lower the standard in order to get a large number of members. We are not organized on the same basis as the big societies, but on a basis of endeavoring to select those who are especially interested in the applications of chemistry, and sufficiently interested to want to come together and discuss the profession of chemical engineering, its possibilities, and its results, and not to be a mere side issue in some big national gathering like the American Association for the Advancement of Science, which has, in fact, swallowed up the meetings of the American Chemical Society once a year; or the American Chemical Society itself, which is now swallowing up the interests of a number of different sections with totally different aspirations and totally different interests. We want, therefore, to develop the Institute on a really substantial basis, and we must proceed moderately. If each individual member would see if he cannot within his personal acquaintance pick out the names of three or four of his friends,

who, he believes, would be qualified to be useful and valuable members, we can probably double our membership, and perhaps treble it. There is nothing more of a general nature, and we will therefore not hold the members longer.

The members of the Council will please remain behind for a few minutes, as there is one matter that the Council should settle.

Meeting adjourned, 5:30 P.M.

A subscription dinner was held at the Brighton Beach Hotel in the evening. A considerable number of guests were present and a number of enthusiastic toasts given.

Excursions Friday, June 25

9.30 A.M.

Excursion to the Atlantic White Lead and Linseed Oil Works, foot of Gold St., Brooklyn, N. Y. (The manufacture of white lead, linseed oil, lead pipe and sheet lead.)

11.30 A.M.

Through the courtesy of the National Lead Company, their steam lighter *Atlantic* conveyed the members of the Institute and their guests up the Hudson River.

1 P.M.

Excursion through the Edgewater plant of the Corn Products Refining Company. (The manufacture of glucose, starch and corn by-products.)

3.30 P.M.

Excursion through the Edgewater plant of the Warner Sugar Refining Company.

5.30 P.M.

Return trip on the steam lighter *Atlantic*.

Luncheon and refreshments were served on the boat.

Excursions Saturday, June 26

9.30 A.M.

Excursion to the Standard Oil Company's plant at Bay Way, N. J. (The refining of petroleum and by-products.)

Through the courtesy of the Standard Oil Co., the members of the Institute and their guests were conveyed by a steamboat to Bay Way, N. J., and back to New York.

The plant of the Consolidated Gas Co. at Astoria, L. I., was visited during the afternoon.

On Monday a number of members inspected the large new station and tunnels under New York city of the Pennsylvania R. R. Co.

SECOND ANNUAL MEETING

HELD AT HOTEL WALTON, DECEMBER 8-11, 1909, PHILADELPHIA, PA.

WEDNESDAY MORNING SESSION

President Sadtler called the meeting to order at 10 A. M., and introduced Mr. Gleason, Secretary to, and representing the Mayor of Philadelphia.

Mr. Gleason:

Mr. President, Gentlemen of the American Institute of Chemical Engineers: I am very sorry that His Honor the Mayor could not be present. He was called out of the city this morning, and has asked me to convey his regrets and his sincere well wishes, and to give you a hearty welcome to the city of Philadelphia. He would have been glad to be here if it had been at all possible, but his engagement is of such a nature that it was impossible to postpone it, and, much to his regret, he was forced to accept.

Philadelphia is a city of varied interests, and I hope that you will find your stay a pleasant and a profitable one. We are glad to have you come here, because Philadelphia represents a scientific development, because the industries of Philadelphia have not been developed with one thought, nor along one line. Experimentation and theorizing have been carried on only so far as they would produce positive material gains, and it has been this applied science and this applied industry that has brought Philadelphia to the front. Philadelphia is recognized to-day more as a city of homes and industrial development, but the Philadelphia of to-day has not been made by development along one line; it is a city of scientific development. Its schools and colleges are known throughout the Union and throughout the world. They are not, perhaps, so familiar as colleges of other cities or lands, because Phildelphia's development has not been one-sided, and, perhaps, here industrial

prosperity has become so dominant that scientific development has been overshadowed, but the institutions that are flourishing in the city to-day bear witness to Philadelphia's recognition of the fact that the business methods of to-day differ from those of the past, and of the importance, and necessity, of scientific education in order to compete successfully with the products of other lands.

The Society will find many interesting places in the city, and I notice that the filtration plant is mentioned as one of the works that you are going to visit during your stay. The filtration plant is a plant of which Philadelphians are justly proud. It represents a work of great magnitude, and it has won for Philadelphia a certain amount of fame. Engineers are to-day coming from all over the world to see it. Plans are now being made for the construction of a sewage-disposal plant. By an act of the legislature of the State it is necessary that the engineers working for the city submit by the year 1912 plans for the construction of a sewage-disposal plant. Experiments are now being carried out at the old Spring Garden Pumping Station, for a plant adequate to meet the needs of Philadelphia. Philadelphia covers 129 square miles and has one and a half million inhabitants, and the sewage plant is being planned on a scale sufficient to provide for the future growth of the city. The engineers are studying various methods of sewage disposal with the view of planning and constructing the best sewage-disposal plant in the world. While Philadelphia's filtration plant to-day is a matter of pride, it will be nothing as compared with the finally completed plant.

The business methods of the present, I have said, are not the business methods of the past, and no city has realized better than Philadelphia that scientific development must go along with industrial development. There are in all parts of the city large plants, showing just what Philadelphia has done along these lines. She has progressed as well as any city in the Union. I note that you are going to visit various plants throughout the city, and I also note that there are gentlemen here from the Dupont Powder Works, and that officials of the Powder Co. are among your members. They represent a growth which Philadelphia may lay claim to, and of which she is proud. While the plant is entirely outside the city limits, it is a feature which we have to take cognizance of, because sometimes when a careless workman fails

to carry out the instructions of the superintendent we are forcibly reminded of the existence of such a works.

The problem of the future is the problem of the conservation of national resources, the problem of scientific development along industrial lines, and of industry along scientific lines. Philadelphia is proud, therefore, to welcome the Institute of Chemical Engineers, which is engaged in this work. I hope that your stay will be profitable, and that you will be glad that you were here, and will go away with the proverbial hospitality of Philadelphia engraved upon your hearts and minds. It ill becomes a host to speak of his "proverbial hospitality," but Philadelphia wants you to feel that every possible courtesy that she can extend to you, she will be only too glad to extend, and that the hospitality is not only proverbial, but positive and real.

Pres. SADTLER:

I desire to thank his Honor the Mayor, through Mr. Gleason, who so ably stated on his behalf the position of Philadelphia, and the feeling which exists here toward the Chemical Engineer. I am not myself coming to Philadelphia for the first time, having lived here for thirty-five years, and I do not think that a majority of the gentlemen here are strangers to Philadelphia, because they know something about these plants. When Philadelphia was mentioned as a place for the meeting, a great deal of interest was displayed and a strong desire expressed to come because they knew of these plants, and I have been told already this morning that the program is an extremely attractive one. We have a great deal here to show you. In 1904 we entertained the British chemists—The Society of Chemical Industry—and at that time endeavored to give them some idea of the historic development of chemistry in Philadelphia. The chemical industry is older in Philadelphia than in any other city of the Union. Three or four of its industries go back practically a century or more. Along the lines of applied chemistry, in the manufacture of textiles, of leather and in the refining of petroleum, Philadelphia stands at the present time almost—if not quite—pre-eminent. The largest industries in the country along these lines are represented here. However, it is not necessary to take more of the members' time in that subject, and I wish to thank you [Mr. Gleason] for the expressions made on his [the Mayor's] behalf. The members will appre-

ciate very much the opportunity to visit the municipal plant; and, if time allows, will be very glad to look into the other question of sewage disposal. Among our members we have some men eminent in the line of conservation of resources, and men connected with municipal improvement work, and I know that they will enjoy very much seeing what Philadelphia has done. I thank you again on behalf of the Institute.

The ballots for officers for the ensuing year are as yet unexamined, and I would appoint as a committee to look over the ballots, and to report as soon as possible, Mr. Adamson, Mr. Renaud and Mr. Carnell.

We are ready now to proceed with the business of the session. The first matters in order are the reports of officers and council. One of the most important committees is the Membership Committee, which meets regularly throughout the year. Dr. Langmuir is the chairman of that committee, and I should be very glad to have his report if he has it ready.

Dr. Langmuir read the following report:

Report of the Membership Committee

Two meetings have been held since the last report of the Committee at the semi-annual meeting in Brooklyn, June, 1907. Two Institute ballots have been canvassed, 54 and 70 votes being cast, 4 candidates were elected on these ballots, bringing the membership up to 104. Nine applications were acted upon. Three candidates were recommended for election. Four were under age. The occupation of one candidate was not considered that of a chemical engineer. Definite action on one candidate was postponed until the recommendation of members of the Institute could be submitted. Three applications in the hands of the Secretary are unacted upon.

The vote of the Institute on the adoption of the benzene ring, as the permanent insignia of the Institute was canvassed. So much opposition was manifested that a selection was made from other designs proposed by members and a very simple form submitted to the members, with the result that the design A has received 16 votes, while the design B has received 44. The design

seems to be generally satisfactory. Some difficulty has been experienced in getting a red enamel of the proper shade, but delivery can soon be made. It is the intention to engrave a member's initials or name on the reverse of the badge, also the letters C.M., for all charter members, and a number indicating the order of admission of each member.

The committee has drafted after considerable discussion an amendment to the constitution providing for the admission of Junior Members. The Membership Committee recommends this amendment to the Constitution for the following reasons:

1. A considerable number of young men have applied for admission and have been rejected because they have not reached the age limit. In many cases, these young men have had most excellent education and are occupying positions of responsibility.

2. Several of the objects for which the Institute was organized would be attained by the admission of such candidates; the most important being the raising of the professional standard among chemical engineers by bringing promising young men under the influence of the Institute during the years when their ideals were being fixed. The association of such men with the older and more experienced members of the Institute would be very stimulating.

The Institute, on the other hand, would be strengthened by admitting such enthusiastic young men, so that their interest in the organization would be maintained until they could qualify as members.

Proposed Amendment to the Constitution

ARTICLE III—MEMBERSHIP

Section 1. Qualifications for Membership.—Membership shall consist of two grades: Active and Junior.

Active Membership shall require the following preparation and training:

[The remainder of Sec. 1 as at present given in the Constitution is inserted here without any change.]

Junior Membership shall require the following preparation and training:

All candidates must not be less than 23 years of age and must

be engaged, at the time of election, in some branch of applied chemistry, and must fulfill one of the following requirements:

1. Hold the degree of Ch.E. (Chemical Engineer), B.S. (Bachelor of Science) in Chemistry or Chemical Engineering, E.E. (Electrical Engineer), C.E. (Civil Engineer), M.E. (Mechanical Engineer), or equivalent degree from an approved university or technical school offering at least a four years' course.

2. Have had five years' experience in Applied Chemistry.

Junior Members shall have all privileges of the Institute excepting those of voting, holding office, and wearing the emblem or badge of Active Membership. A suitable emblem or badge of Junior Membership as adopted by the Institute may be worn by the Junior Members. When qualified, a Junior Member may apply for Active Membership. but must do so before reaching the age of 35, otherwise his membership shall expire.

SECTION 2. Amend the second sentence to read: "The applicant for Active Membership shall give the names of at least five members to whom he is personally known."

Insert the sentence: "The applicant for Junior Membership shall give the names of at least five persons to whom he is personally known, two of whom shall preferably be members of the Institute."

SECTION 6. DUES.—The entrance fee for Active Members shall be $15; Junior Members shall pay no entrance fee. Annual dues for active members, $15, for Junior Members, $10. Junior Members on becoming Active Members shall pay an entrance fee of $15, less $1 per year for each year of their membership as Junior Members.

DR. A. C. LANGMUIR,
Chairman.

Recommendations regarding Junior Membership explained by Dr. Olsen

DR. OLSEN:

Summing up the recommendations: The Junior Member can enter at 23. He must have a college degree, or what, by our Constitution, is considered equivalent—five years of practical experience. He must be employed when he is admitted. This amend-

ment does not provide for any length of employment if he is a college graduate. Junior Membership ceases at the age of 35. In the Society of Civil Engineers it ceases at 32, but the difference is that this Society may admit him to a lower grade of membership, i.e., associate membership, and later on to full membership, while in our Society we would have to admit to full membership or drop him—hence, the upper limit of 35 years, giving five years leeway. The Junior Member is, of course, a member of the Society, and gets the publications, and the notices of meetings, and may be present, but cannot hold office or vote, and cannot wear the badge of active membership. A suitable badge can be adopted. Ten dollars is the annual due for Juniors, with no initiation fee, on the ground that the latter might prove a serious objection to a young man. Believing as a committee that the Society will be made stronger by these young, energetic men who are applying at present for membership—good, capable, promising young men—it would seem as though it would be a benefit to them to be admitted, and, from the standpoint of the Institute, that it would be an advantage to the Institute to have them admitted, because its influence would be beneficial to them, and they ought to be more desirable as members when the time comes for their full association with us. It is difficult to see what possible harm can result.

Pres. Sadtler:

Gentlemen, I think this matter had better be discussed now to a moderate degree while we have it before us. There are copies of the Constitution here on the table. We have only one grade of Active Membership, and I suppose most of you are familiar with the qualifications for admission as they now exist. I did not take part in the discussions of the Committee on Membership, but I am in general in accord with these views which have been stated, and I would like to hear from some who have discussed the matter before, and who possibly have better knowledge than I have as to what class of young men would form this Junior Membership.

Mr. A. C. Langmuir:

The discussions of the Membership Committee were generally with regard to the age limit at which Junior Members should be admitted. The Committee was unanimous that they should be

admitted, but there was some discussion as to whether the age should be 23 or 25.

Dr. L. W. Andrews:

I would like to ask whether the fourth requirement of Section 1 on Membership applies to these Junior Members.

Mr. J. C. Olsen:

No, that was not put in, as I recall it, and the reason was this: Admitting at 23, we considered that we could admit on the college degree. Now the degree of "Ph.D." under our Constitution may be taken as the equivalent of three years practical experience after the college degree, and we therefore considered that that was unnecessary, in that the Doctor of Philosophy has had the college degree, and we considered that to be sufficient for a Junior member. That would be a requirement which would be considered when be applied for full membership. If he had his "Ph.D." he might be admitted to full membership after two years of actual experience.

Dr. L. W. Andrews:

I asked the question because I happen to know two young men under the "30 year" limit, but who will pass that limit within the year, and who desire to enter the Institute. Both these men took their doctor's degree at the same institution, but one of them is a man of greater ability than the other. He took his degree in two years, while the second man required four. Now under this paragraph of the requirement, as it reads, the man who took the four years to get his degree might receive the deduction of that four years from his five years of practical experience, whereas the man who accomplished the same feat in two would only get credit for two years.

Sec. Olsen:

It is optional with the committee whether they will allow these four years. They would have to consider in that connection general ability, work and recommendations.

Dr. L. W. Andrews:

The implied suggestion is simply that the number of years credit to be given for the doctor's degree might be fixed, instead of being flexible so as to be unfavorable to the man of greater ability.

Mr. Frederick Dannerth:

It has occurred to me that we might leave 30 years as the limit at which a member might pass from the Junior condition to the Senior or full Active membership. Why is it necessary to extend that to 35? You might have the new paragraph apply as soon as he reaches 30, then to become eligible to Active membership in the Institute, or to be dropped from the list. The present statement in the Constitution is 30 years as the lower age limit.

Sec. Olsen:

We will admit them now at 30. But we should not drop a Junior from our membership roll at 30, because many men of 30 may not have been in responsible charge of work for five years, as must be the case in order to be eligible for membership. A man may be very promising at 30, who may not have graduated from college until 25. At the Brooklyn Polytechnic Institute, the average age at matriculation is 21, and a man is 25 when he gets out, and he may then have to spend two or three years in a subordinate position. If we cut him off at 30 that will throw many able men out of the organization for a few years. We should allow him to stay in until he is 35 and has the full requirements for membership.

Pres. Sadtler:

If you force him to make a choice at the age of 30 you will be cutting him off. I think it very wise to allow these five years latitude or range in which this option can be taken up.

This discussion is, of course, merely a calling forth of views. No action can be taken at present. The matter must lie over until the next meeting, and in the meantime the matter will probably be put in printed form, so that members can study it before being called upon to vote upon it.

Secretary Olsen then announced that a design for a membership badge had been adopted by letter ballot, and that badges were being made. The badge adopted is a shield with the words "American Institute of Chemical Engineers" in gold letters set in red enamel.

Pres. Sadtler:

The next report called for is the Treasurer's report.

Treasurer's Report

From Dec. 1, 1908, to Dec. 1, 1909

Balance in the bank December 1, 1908	$ 39.55	
Received from members during the past year	1453.08	
Interest	5.02	$1497.63
Disbursements:		
Exchange	7.70	
Postage, printing, stenographer's fees, plates used in printing the volume	1088.40	1096.10
Balance in the bank, December 1, 1909	.....	$ 401.55

Up to the present date, there are bills receivable to the amount of $80, bills payable on account of volume to the amount of $574.48, so that, having received nothing from the sale of the volumes, there is a deficit of $92.93. As I understand that twenty volumes have been sold at $6, this deficit is more than covered.

Respectfully submitted.

Wm. M. Booth,
Treasurer.

Pres. Sadtler:

If there are no remarks to be made, the reports of committees are next in order.

The committee which was appointed upon "Chemical Engineering Education" of which Dr. McKenna is Chairman, will now make its report.

Report of Committee on Chemical Engineering Education

Your committee having met with a serious loss in the death of the lamented Hunicke, and being otherwise prevented from beginning its work as early as was wished, desires to submit only a progress report, and asks for continuance that it may be able to carry out certain plans it has in process of formation whereby full and correct information may be obtained of the present condition of chemical engineering education in those institutions of the world where learning flourishes and necessary material equipment is not denied.

It asks also the encouragement of every member of the Institute, any one of whom may receive during the year communi-

cations of inquiry as to his knowledge of what is taught on this subject in some institution he is familiar with, or as to his views as to what ought to be taught, how the teaching should be done or what the results are in our present-day teaching as he finds them, in his opinion.

Your committee after thus having acquainted itself with these facts will, for the first time, be in a position to draw conclusions and report to your body for such a full discussion as may lead to the advancement of this branch of learning, its progress and its application.

The committee does not feel that much time has been lost. It appears that chemical engineering education has been going through a condition of flux for a short period of two or three years, and, judging by results, much improvement is being manifested. The young men we casually come across now practicing chemical engineering are certainly of more advanced scholarship, and a more devoted type of men than formerly. The time is just about ripe now to make this investigation thoroughly. It may include the investigation of chemical engineering education in the universities abroad. We cannot be certain of that. We are not certain that our subject, as dictated, includes that, unless incidentally, but if there are any suggestions to be offered we would be glad to hear them now, and we present this as a "progress" report.

CHAS. F. MCKENNA,
Chairman.

Mr. J. C. OLSEN:

I wish to make just one remark with regard to the report on education. Dr. McKenna has said that there is no pressing demand for this report, because chemical engineering education is in a state of flux. I wish to remark that this is a very urgent reason for an early report. At my own institution the chemical engineering course is at present being, or rather, has been fluxed, which consisted in making it a five- instead of a four-year course. There were quite a number of questions which arose in connection with the change, and I should have been delighted to have had the aid of a report from a committee of this body, on what they considered to be the essentials of such a course. It fell upon me to draft that course, and there were a good many points and questions which arose with reference to what we should include or exclude

from this course. We have tried a four-year course in chemical engineering, and have found that only the brightest, strongest men could carry it. We have decided now to try a five-year course. We have to include in that period chemical training, mathemetical training and engineering training. How much of each should be given was a serious question with us.

One particular question arose with reference to our course leading to the degree of B.S. in chemistry, and we are debating it at present, and that is: Shall calculus be included? I have asked a good many men if they have used calculus in practical work, and I have not come to any definite conclusion as to whether calculus should be included in the course mentioned. Of course we are forced to include it in an engineering course, on account of the engineering subjects which must be given. There are a good many of these specific questions upon which the schools would be glad to have the advice of practical men, and the sooner this report goes out the better, I am sure. The educational institutions will welcome it, and I think they will feel that the Society is doing a genuine service to education by giving them its views upon what ought to be done in a four- or five-year course.

Mr. McKenna:

With regard to the last point, I would like to have the views of the members of this body. It is a topic to spend time on. One of our members raised another question upon which I would like your views. That is, what would you recommend as to the mode of dealing with the subject of teaching qualitative analysis? Should not qualitative and quantitative analysis be considered simply as chemical analysis, and quantitative operations be introduced as early as possible in the work of the student? And what will be considered by men of experience now having a past behind them to judge by, as the proper element of time to be given in the curriculum to chemical analysis. You can think of a score of such points that will have to be touched upon, and the basis for judgment will have to be found by consultation with officials in the most prominent institutions. If any of the gentlemen now present have decided views upon any of these questions it will be well for the instruction of the committee to have their views.

Pres. SADTLER:

The members of this Committee on Chemical Engineering Education, appointed at Pittsburg, are: Chas. F. McKenna, Chairman; Wm. J. Booth, David Wesson, Ferdinand G. Wiechmann, and L. W. Andrews. These are the gentlemen who want to hear from you on this subject.

President Sadtler stated that a telegram had been received from Mr. Smatolla: "Am sorry cannot attend meeting. Am lighting producer plant." His paper was therefore withdrawn.

Pres. SADTLER:

I would call for the report of the committee to canvass the ballots. Mr. Adamson has the report, I think.

Report of committee read. (List of officers elected and committees appointed by President McKenna will be found on pages 55, 56.)

Mr. FRERICHS:

Gentlemen: When, about two weeks ago, I received this ballot, I was very much surprised to find my name upon it as candidate for President, and I felt at once that Dr. McKenna ought to have the election. For that reason I wrote at once to Dr. Olsen, asking him to kindly request the gentlemen who had put me in nomination to turn their votes over to Dr. McKenna. Dr. Olsen wrote me that it was too late, and that if anything of that kind was to be done, it would have to be done here in Philadelphia. In view of Dr. McKenna's great interest in the Society I felt that he ought to have a unanimous vote, and I wrote the letter for that reason. I beg to move that the election of Dr. McKenna be declared unanimous.

The motion was seconded and passed unanimously.

Pres.-elect McKENNA:

Gentlemen: I am like the young lady, "who, swearing she would ne'er consent," etc. I made an honest effort to avoid the honor—a strange position to take, for it is a very great honor for me. I think you appreciate that as much as I do. But, with a feeling of diffidence, and regard for some other interests, I did strive hard to avoid it, and I made use of a fellow member, who, perhaps, has been misunderstood in the matter. But I had wished, and do wish now really that such an honor had come to our very

excellent friend and brother, Dr. Frerichs. I cannot but express the feeling that the future has something in store for him in appreciation for what he has done. I can only say that some of the difficulties that I foresaw have evaporated, and that consequently I feel that I can promise a devotion to the interests of the Institute, which, let us hope, and with your help, I feel quite sure, will result in an advance. We will not be too hopeful, but we will advance, and there is nothing that you ask me to do that I will not strive hard to do. I thank you sincerely.

Pres. SADTLER:

You now have a real president elected. I was a makeshift and a "stop-gap" when the Society organized, and I am very glad to see that we are now going to have an active, energetic man to direct the Institute, although I tried to do the little I could. I would say that, according to the Constitution the Vice Presidents move up in order, and there is a vacancy now in the First Vice Presidency, which will be filled by the Council. The Second Vice President under this arrangement is Dr. Edw. G. Acheson of Niagara Falls, Third Vice President, Dr. Eugene Haanel of Canada.

Meeting adjourned 12 M.

WEDNESDAY EVENING SESSION

Meeting called to order by President Sadtler at 8 P.M.

President Sadtler requested the Secretary to read the resolution prepared by the special committee, to be forwarded to the Congress on the Conservation of National Resources. The resolution as read was unanimously adopted.

Whereas, We, Chemical Engineers now in session in the city of Philadelphia, and being directors of many industries, recognize that in the near future there will be a very large demand for water power in the chemical industries; that this will amount to a revolution in many of their branches; that the full development and application of water power will be not only an aid to navigation, but such help to industries that the States and the nations will be repaid the cost of such developments on financial plans similiar to those of the irrigation developments in the arid West; therefore,

Resolved, That the American Institute of Chemical Engineers respectfully urges upon the National Rivers and Harbors Congress now assembled in Washington the great importance of forestry and water storage; that it also respectfully urges that hydraulic, chemical, and electrical engineers should be associated with other engineers in so determining such important question that a true and thorough co-ordination of every interest may be obtained for the good of all our people and the highest development of every interest.

It is further resolved that a copy of these resolutions be forwarded to the National Rivers and Harbors Congress now assembled at Washington, D. C.

J. C. Olsen, Secretary. Chas. F. McKenna, President.

President Sadtler's Address was then read,

Professor Chas. E. Munroe addressed the Institute on "The Chemical Industries of America."

Pres. Sadtler:

We have listened to a very carefully prepared and very satisfactory presentation of this subject, at the hands of Professor Munroe, who has had exceptional opportunities for getting this information, and the chairman would entertain a motion for expression of the indebtedness of the Institute for the paper which he has prepared.

Motion made, seconded and carried.

Meeting adjourned.

FRIDAY MORNING SESSION

President Sadtler called the meeting to order at 10 A.M., and proceeding to the installation of officers, said:

The first matter on the program for Friday is the installation of officers and business meeting. There has been no previous function of this kind, and there are therefore no precedents to follow, and no ceremony is necessary. I take great pleasure, therefore, at the beginning of the meeting to-day, as my first and last duty, in introducing to you the new President, Dr. Chas. F. McKenna, who will preside from this time on.

Pres. McKenna:

Mr. Booth, before leaving last night, asked me to present a matter, which I have handed to Dr. Sadtler to present.

Ex-Pres. Sadtler:

The matter which Mr. Booth spoke of was this. A year ago, when we met at Pittsburg, the matter was discussed as to whether it was desirable for the Institute to undertake to find some one to establish a medal to be awarded annually by this Institute. We have, irrespective of the award of medals like the Carnegie medal, the award regularly every year of the Perkins medal, under the control of a combined committee, and the award every year of the Nichols medal, controlled by the New York section of the American Chemical Society. It is very desirable that in the early work of this Institute we have a medal established, to be known as "The Institute of Chemical Engineers' Medal," awarded every year for the best work submitted to a committee of members of the Institute—some work in industrial processes, or chemical discovery valuable in the arts. Nothing came of the matter during the year. It was simply talked of. We have really made no effort to find an individual willing to establish such a medal, but there will be no difficulty in doing so. In the meantime, without waiting for that, it was thought in discussing the matter that a few active members of the Institute might temporarily arrange for the establishment of such a medal and have it already put on the program, and later on handed over to some person who would want to make it a personal matter. Three gentlemen said yesterday that they were willing to be three of a group of ten or something like that, and contribute each five or ten dollars, or whatever might be necessary to establish the fund. The amount necessary would be very small. After the die was made the annual striking off of a gold medal would require very small expense. I merely bring the matter to the attention of the Institute to-day and ask for an expression of opinion. If any individuals want to co-operate they can speak to Dr. McKenna, or some one else who will have the matter in charge, and we can easily accomplish the thing. There will be no trouble in getting together the necessary group who will do it as a temporary matter, and I believe that it will be very easy to find some one who will be glad to do something of this kind personally.

Pres. McKenna:

Mr. Booth was very enthusiastic about this, having presented it last year, and was sorry to see a year go by without its being started, and wished to start it himself in this way. I thought it a project well worthy of encouragement. Perhaps the best way to further it would be to have some members appointed to care for that subject, to draw up all the requirements and safeguards necessary to perfect the scheme, and there is no doubt, as Dr. Sadtler said, but that in the present year, and for a few years to come, there will always be enthusiasm enough to secure contributions of moderate sums towards procuring the medal, and later perhaps some gentleman will be glad to have his name connected with it, and make what is called a foundation.

Mr. F. W. Frerichs:

I think it is a very commendable proposition, and for that reason I move that such a committee be appointed.

Motion seconded.

Pres. McKenna:

It is moved and seconded that a committee be appointed to draft a proposition for the establishment of a medal for the best paper presented during each year before the Institute of Chemical Engineers, to be known as "The Institute of Chemical Engineers Medal," this committee also to look forward to making provision for a permanent medal fund.

Carried unanimously.

Pres. McKenna:

We have before us a report read yesterday of the Membership Committee upon the subject of proposed changes in the Constitution admitting Junior Members. As this matter is now before us for action the Secretary will give a brief digest of the provisions recommended by the committee.

(Dr. Olsen then gave a digest of the provisions as in the Wednesday morning meeting.)

(President McKenna followed this by reading the provisions of the Constitution with regard to amending it.)

Dr. Grosvenor:

It happened that coming in on the train this morning I met a man who is a member of at least three societies, and who has taken

a great deal of interest in the development of our Institute (he read a paper at one of our meetings), and he said: "What are you going to do about Junior Members? I want to recommend that you take the question up and put it through. There is no way in which you can do more good. No way in which you can better ensure your own growth and development, and in the long run raise the standard of your profession, than by bringing up the men from the time they start at college with the idea that the standards of the Institute are so high that they must raise their own standards to meet them; and when they become members this will react and raise your standard." Another thing worth consideration is that, financially speaking, they will be the backbone of the institution.

Ex-Pres. Sadtler:

I do not know that I am opposed to this proposition, but one thing occurs to my mind which looks serious. Of course if the ideals are followed in the way in which Dr. Olsen and Dr. Grosvenor mentioned, there can be no objection, but I am afraid that some of the young men who apply may use the name of the Institute, without prefacing it with the fact that they are Junior Members, and be recognized by the public as members while not possessing the qualifications that we are so anxious to adhere to; and I am afraid that it might let down the barriers very considerably, unless the Membership Committee is very firm in passing upon such candidates. The provision of their being connected with important industrial operations would be a safeguard, but if it were not rigidly adhered to, the barriers might be let down in a very serious way. I am not opposed to the idea of having Junior Members, but we must be very careful in letting down the bars to young men who have no real qualifications.

Mr. Wm. Grosvenor:

I believe there is one limitation placed upon such membership in some other institutions, namely, that the Junior Member shall not in any way refer to himself so that it is not clear whether he is a Junior Member, or a member, and such an offense cancels his membership automatically. That was one point that was brought up in speaking of the matter this morning.

Mr. H. S. Renaud:

The plan as outlined also drew attention to the fact that the Junior Member was not to wear the insignia of the Institute. We could have an appropriate badge to show that he was a Junior Member, and this would make the distinction right away.

Dr. J. C. Olsen:

I would like to ask one question. The Constitution provides that a copy of this amendment shall be sent to all members. I would like to know if its appearance in Volume II of our Transactions as a portion of the report could be construed to cover that provision, or if I am instructed to have separate copies made or printed and sent to members.

Pres. McKenna:

I think, if I were asked to rule, that it means a separate notice and not the mere insertion of it in the volume of Transactions. The Constitutional provision is drawn up with the intention of being specific in pointing out what is proposed to be done, so that it would not be lost sight of.

The amendment was laid upon the table.

Ex-Pres. Sadtler:

It was suggested that another alteration or change might be made in the Constitution. At the present time the President is not eligible to re-election when he goes out of office. Now it might be that during the year that he had served, a great deal of particular information would be gathered by him on certain matters, which he would like to discuss in the Council, and at present he has no opportunity of doing that unless by election into the Council. This is not desirable, because it simply puts up to the members the question of electing the retiring President, and putting someone else out. The Electro-Chemical Society have a provision by which the retiring President serves, by reason of his being the retiring President, for three years as a member of the Council, and is then automatically dropped from such membership, the distinct purpose of the provision being that his experience during his term of office shall be available to the Council. To article four, page eight of the Constitution, we might add, that the retiring President shall for the term of two years be considered as a member of the Council, and at the end of that time drop out.

There will then always be two ex-Presidents acting with the Council who will not have to be elected as members.

I have no personal feeling in the matter, because the members of the Institute have already elected me to the Council. I was rather sorry, because I would rather have them bring up three new men. It would be an advantage when the President retires to have him serve for a period of, say, two years. The next year there would be another retiring President, and all the time there would be two men furnished from the service as President acting with the Council.

Pres. McKenna:

We will accept that as a proposed amendment to the Constitution by Dr. Sadtler. At the first regular meeting hereafter the subject will be discussed. It is an important one, and the Constitution will be improved, I have not much doubt, by having it included.

Amend Article IV, Section 1, by inserting in the eighth sentence after "The President," the words, "Ex-Presidents for two years succeeding the expiration of their term of office as President."

We have to determine before the close of this meeting, where the next meeting shall be, although it can be left to the Committee on Meetings, but it would be better for all to know now where the next meeting is to be held. I can say to you that already the plans for the next meeting are under way, and the coming meeting promises to be equally as important as this very excellent meeting which is now going on.

Sec. Olsen:

It seems to me that the same objection to a final decision would be raised here as was raised in Brooklyn, that we would have to consult members in the towns where we would think of holding the meeting before final decision. Toronto has been suggested as a place, but it seems to me that we would have to consult with the Canadian members to see if they could make all necessary arrangements for the excursions, and obtain permission to visit works at Toronto or Niagara Falls. We might merely pass a resolution that if it were found to be feasible, the Institute is in favor of holding their next meeting in Toronto, Buffalo, Niagara Falls or the Lake region.

Pres. McKenna:

I should be pleased to have the members express their views as to whether they would like to see a meeting held about the second week in June at Toronto, or Niagara Falls, or whether any other city would be preferable.

Mr. M. C. Whitaker:

The success of a meeting depends very largely on the co-operation that is gotten from the local committee. It is pretty hard to tell offhand just how the local people are going to take the suggestion to meet in their town. I think it is better, therefore, to appoint a committee to recommend, or even determine finally, the date and place of the meeting, after correspondence and canvassing the situation, so as to ensure the right kind of reception. I do not think we can settle it offhand, or that we should force our presence upon a community. I would like to suggest that the committee be given authority to canvass the situation, and advise us at a later date as to what their judgment is, and by all means give way to the judgment of the men who have studied the situation, and found out what the conditions are.

Dr. Wm. Grosvenor:

I beg to move an amendment to the motion: That it be made the regular business of a committee to make such a canvass sufficently in advance of the semi-annual meeting, so that it can be acted upon by the members at that meeting.

Pres. McKenna:

The motion is before you: That the Committee on Meetings be charged with the selection of the place and time of the next meeting, and to report at each semi-annual meeting; and be given authority, after making their investigation, to make the selection.

Motion carried.

Meeting adjourned.

TUESDAY EVENING SESSION

President McKenna called the meeting to order at 8 P. M. and announced the election of Dr. F. W. Frerichs of St. Louis as Vice President, to fill the vacancy caused by the death of Dr. Hunicke.

Pres. McKenna:

We will now proceed to the reading of papers. So much interest has been manifested in Dr. Andrews' paper on Peroxide of Hydrogen that I will ask the Secretary to read it.

(Reading of Dr. Andrews' paper by Secretary Olsen).

Ex-Pres. Sadtler:

One and a half years ago, when this Institute was formed, we did not have any great doubts about the usefulness of the Institute, but we did not just know how it would be received in the technical world, and we wanted to go a little cautiously, so that we did not have an initiation fee fixed. We put that off until the membership should reach 200, making it an inducement, as it were, to join. Now I think the way a good many of us feel at present, there is no doubt about the usefulness and success of our movement, but there is a great deal of doubt about how many are likely to join—not because a great many won't want to, but because a great many will be kept out. It will probably be some little time, therefore, before the membership reaches 200. I suggest, therefore, a constitutional amendment to the effect that the initiation fee of $15 take effect as soon as the amendment should be passed, six months hence at the earliest, and I would like to ask the Secretary if he will prepare such an amendment dating from this meeting, and that the amendment be discussed at the next semi-annual meeting. It is therefore not really necessary to discuss it now. I would just like to have that amendment entered, and if we come to the point of feeling that it was really very vital that we should do it we can act upon it. I think now is the time to make such an amendment. Amend Section 6 by substituting in the second sentence the words "after January 1, 1911," for the words "the membership shall reach 200."

Sec. Olsen:

With regard to the proposed amendment, at present members joining are charged for back volumes of our Transactions. If we charge an initiation fee we shall probably give the new members one or two, so that it evens things up a little.

Dr. Wm. M. Grosvenor then moved that a vote of thanks be tendered to the various manufacturers, city officials, etc., for their courtesy and the facilities extended to the Society, also that the Secretary be authorized to express our sentiments to them by letter, also that we should recognize the extremely good work of the local committee by a proper vote of thanks to them. They have certainly given us an unusual program, and they have obtained for us unusual courtesies. We hope that our proper appreciation will establish the precedent for more of the same sort of frank, straightforward interchange between the technical man and the manufacturer.

Motion seconded.

Pres. McKenna:

This is a motion which I put with considerable pleasure, and I want to have it recorded that it is not merely a formal motion. It is one that means that our thanks go out in the heartiest way to these gentlemen. In the case of the local committee, as Dr. Grosvenor has said, they have been unusually efficient and happy in their mode of dispensing hospitality, and from each and every one of the firms mentioned and the individual officers of those firms, we have received such extraordinarily kind treatment that it would be well for the Secretary in addressing them to try and let them understand that the vote of thanks was more than a mere formality.

(Motion passed unanimously.)

We have more important matters to consider, which, however, can be left for circular work by mail. I would like to see some of them, however, brought up for initial discussion. There has been very much discussion among the members about some points. The principal one of these is the discussion of the subject, What is the principal duty for the officers of the Society to perform during the interim between the semi-annual meetings? In other words, what is the most efficient way in which the Institute can make itself useful to members, outside of the works which you have seen

performed at meetings, and the publications? Is there no other work remaining for us to do, by which we can make the membership more valuable to those who come in?

Mr. Wm. Grosvenor:

I think you have expressed the need, I may say, the great need of the Institute. We all of us know what we would like to do for the Institute in some respects, and the duty is vested in the Membership Committee to see that only men are admitted to membership who will recognize that duty. But a part of that duty is to determine what the Institute shall do for its members. Ordinarily we are appealed to by the societies to support them from a sense of loyalty—a sense of duty—and duty is at best a rather cold-blooded appeal. If we want to have this a vital institution the question we have got to answer wisely and well, is, What can the Institute do for its members? What appeal can be made to them which shall be irresistible? After all, there is only one appeal which is absolutely general, one thing to which all of us can respond, and that is mutual service. We expect to do something for the Institute, and it is for us to devise ways in which the Institute can do something for each one of us, and for every man in our profession, which he cannot afford to miss or neglect. A number of suggestions have been made. One of these is the acquainting of each member with the abilities of every other member. Specifically, to get up a complete card index, to get each man to forward a rather detailed account of his career and experience, so that a committee can judge first the character of work he is specifically able to take charge of, second, the line of work he is fitted to express a theoretical opinion upon, and lastly, if investigation work has to be carried out, in what direction he is particularly fitted to guide investigation. Upon the first point, the Institute might well ask for the opinion of those with whom he had worked. Differences of opinion need cause no hard feeling, since all the Institute would undertake to do would be to guarantee that he had had that experience, and had in the opinion of those who knew him done the work well.

Many members would be willing to bear the expense of the publication of these cards. A couple of thousand of them would be all that would be necessary. The Secretary would send to each member of the Society a complete, carefully cross-indexed

file of cards, and a similar file might perhaps, with perfect propriety be placed with the bureau at Washington, or in municipal bureaus. The effort would be to connect special fitness with special needs.

Another thing which has been suggested, is that of bringing about a certain degree of co-operation between the colleges, technical schools, manufacturers and the Institute. The manufacturers would be invited to submit what they regarded as the most satisfactory of their apparatus to test by the Institute, the manufacturer to bear the expense of that test and of the publication of the report. The Institute would not undertake to carry out those tests itself, because this would immediately lay us open to severe criticism, and to the charge of control by the big corporations, or prejudice for one cause or another. These tests should be carried out at some technical institution by the students as thesis work, under the supervision of the director of that department. There is hardly an institution in this country to-day which is not crying for problems. We are trying to get a few of them out of that position. One institution after another is asking, What can we take up for thesis work? It is a fact, they are asking for and they want good thesis work. One of the limitations they labor under is the lack of funds and apparatus. Manufacturers would be very glad to provide both apparatus and funds if they could feel that they would receive absolutely fair treatment, and that whatever was done was authoritative. This might be carried out under the general supervision of the technical institution and be published as a thesis of the university or college, and on each of these publications (perhaps in loose-leaf form) there could be imprinted "Carried out under the auspices of the American Institute of Chemical Engineers." This series of leaflets would make such a catalogue as has never been published, and would have a usefulness very few of us dream of, though we know how hard it is to get just the information we want when passing upon apparatus. If we could keep our skirts clear so that we should not be open to criticism, it would be very valuable work.

There have been several other points suggested, among them, one that during the interval between meetings, in fact a year or so ahead, the Secretary shall carry on correspondence with various men interested in various lines of work, and work up a definite scheme of papers looking in the end towards what the Institute in its inception hoped some day to bring out, an up-to-date chem-

ical technology—one that is something less than twenty years old.

There are a lot of other things of that sort. Every one of them presupposes the careful, thoughtful attention of a man, to give a large majority of his time to the work of the Institute; a paid, salaried man; a man to whom we can look for the best possible results. I do not think we would have to go far to seek him. The question is rather one of salary. Can the Institute afford to pay a salary? Can it afford not to? I do not think it can. An acquaintance of mine is getting a high salary for just that kind of work for the society he represents. He was formerly a manager of one of the Westinghouse plants, and the Society had to pay him handsomely. That is the kind of man we want. We must make the Institute so valuable to the men in our line that they cannot keep away from it. It should be the most real, live institution in the country (if we can do enough of these things) outside the American Institute of Mechanical Engineers. Judging from what I have heard from their men this is a little what they are doing.

I have been thinking about these things a good deal and believe the thing we have got to do is to go to each man with a direct, personal appeal—What can we do for you? Does it not all boil down to dollars and cents? I do not think Americans care merely for money, but it is the "marker" in the game. After they have it they give it all away for libraries. It is the commercial measure of value. Indeed, institutions of the highest moral standards measure their worth by it to a great extent. The missionary societies and the churches recognize it and publish the expression of the good work they have done partly in terms of dollars and cents. We do not wish to put the work of the Institute in a sordid commercial light, but the success of our work can be measured in the success we achieve in the general commercial transfer of valuable services. If I have failed to be ethical, I have failed in the expression of my meaning.

Pres. McKenna:

Dr. Grosvenor's ideas are extremely good and important, and without asking him to put anything in the form of a motion, I should like to see this discussion continued.

Sec. Olsen:

Dr. Grosvenor's suggestions are very specific, and that is a good point; we know exactly what he desires to have done, and he is prolific in suggestions as to what we are to do. As I remarked to him, the other day, he would have the Secretary working week-days and Sundays. Now two of these suggestions are very specific, so that we can act on them. The first is in regard to the card system, in which every member has his career given. I know that a good many of our members are glad to keep on file the technical career of the candidates for membership, as they are sent out for the ballot, and I would like to know if those present file this information. In this way we can easily find out how many members actually consider this information valuable. To put the thing in permanent form, the information would have to be printed on cards of uniform size and arrangement. If it is necessary to fill out any of the careers and put in things which are not regularly put down, the information can, of course, be gotten from the individual members. There has been a suggestion made that the Institute send out to its members a bulletin semi-yearly, and we propose to send out such a bulletin in the near future, and state what has been done at this meeting, and the suggestions made. I propose to ask in that bulletin how many members would consider such a card system of value.

The second part of the suggestion was his method of financing it—each member to bear the expense of his own card, which would be between $5 and $10, I think. That is again specific, and inside of three months we can ascertain what the opinion of our members is on that question. To this method of financing there is one difficulty which may be serious. There may be a fair number of members who will say that they do not care to have such a card, and therefore do not desire to pay for it, and therefore only a portion of the members will be represented. Whether we want to do the thing in that half, two-thirds or three-quarters way is questionable. That, I think, is a serious obstacle to the scheme in its present condition.

Dr. Wm. M. Grosvenor:

I think it might prove a very serious obstacle. I wanted that kind of information, and obtained replies from about 20 of 100 members whom I asked for it. That was just an individual action,

and I called up Dr. McKenna before taking it because I wanted to make sure of its propriety. I certainly find the information very useful.

Sec. Olsen:

As to the second suggestion—to test apparatus, and to do it at the technical schools. There is a certain dearth in some cases of subjects for theses. But there is also a certain dearth of ability on the part of the students who do the theses to carry out such as we may give them. The result of investigations carried out for this purpose is that by the time the student is through with his thesis, he is just about ready to begin. He has found out what he is to determine, and has acquired a fair facility in carrying out the method. Occasionally we find students who by getting summer work in laboratories and working continually, acquire considerable ability, so that by the time they reach their senior year they are able to do something, but a large number of theses are far beyond the ability of the senior of the college or technical school. We have to select a subject for a thesis that will bear fruit in a year upon poor soil with poor fertilizer, and a great many troubles come up. We have to produce the product (graduates), and unless there is good reason to the contrary must have results at the end of the year.

Dr. Grosvenor:

I meant to suggest that one reason why it was difficult to get results was because the staff of most institutions was insufficient to take up the particular problem with the particular man, and take him accurately through it.

Mr. Hollick:

That amounts to the professor doing each thesis, which is just what you want to avoid.

Dr. Grosvenor:

Would he not gain as much if the Institute appointed a man to co-operate with the instructor in carrying out the test?

Mr. Hollick:

I think that impracticable. [After explanation by Dr. Grosvenor] I misunderstood you. I thought that the Institute was

to provide a man to pull the students through the work. I see what you mean—merely to get them in touch with the problems.

Dr. Grosvenor:

The manufacturer wants his problem solved, or his advertisement written—call it which you please—but so long as it is reliable information that is to his benefit, so much the better.

Dr. Frerichs:

The manufacturer applies to the Institute, which brings the school into connection with the manufacturer, and brings the works and the student to work out the problem together, with the criticism of someone designated by our Institute.

Sec. Olsen:

We have done this at the Polytechnic Institute of Brooklyn in a number of cases recently.

Dr. Grosvenor:

One manufacturer in the city told me that he had at least fifty problems in the determination of the efficiency of apparatus that he would like to have made. Another concern appropriated an average of $3,000 a year for not less than three years.

Sec. Olsen:

A certain limited amount could be done, but I do not think it could be done on any very large scale. If the manufacturer devotes very much money to tests of that kind, will they not get better results if they hire a man of technical ability, and have the tests made in their own works, or in some consulting chemist's laboratory?

Dr. Grosvenor:

The main value of a test carried out in the way suggested would be that it would be done quite outside of the manufacturer's jurisdiction.

Dr. Frerichs:

I believe that an endorsement obtained from this Institute in this way, as a result of tests carried out under its auspices, would be very much more prized, because the Institute does not reap any private benefit. Its recommendations would be entirely

impartial, since it merely endorses the results obtained and receives no compensation.

Sec. Olsen:

Institutions of learning are like all other institutions, their funds and their professors are usually fully employed, and the tests would take a certain amount of time. The institution may say—perhaps not in so many words—Why should we do it—give away the use of this time and ability?

Dr. Grosvenor:

I know of at least three commercial concerns which are giving scholarships for this kind of work in the institutions of this country. While I was at college I felt very strongly the need for close personal touch with the men who were doing outside work, and the problems which come up outside.

Sec. Olsen:

We get a line on that in our excursions. Some of our students do not go unless compelled to do so. If we arrange for an excursion once a week on the one hand, and once a month on the other, we get the same total attendance per month in both cases, if we get fifteen to go once a month, we will get four once a week. The amount of interest you can get in that kind of thing is strictly limited. There is a certain amount which can be done, and it is valuable, but, as far as carrying it out on an extensive scale is concerned, I do not believe it is possible.

Pres. McKenna:

I think Dr. Grosvenor is on a little dangerous ground on that last proposition. If he will think it over, and draw it up in terms most likely to bring forth an expression of views from the other members, it can be sent out in the bulletin or circular which the secretary expects to send out within four or five weeks.

Sec. Olsen:

I would suggest, Mr. President, to bring this to a head, that in addition to including this matter in the bulletin and asking for the opinions of members, it be referred to some committee to canvass and discuss. I do not know, just at the minute, what committee would undertake that, or whether, Mr. President, you

wish to have a special committee appointed on matters of that kind, that is, these cards giving the member's technical career, and also the matter of tests.

Pres. McKenna:

I think the best proceeding to follow would be to allow it to go to the Council. I expect to appoint an Executive Committee in the Council, who will meet somewhat often. They will not abuse your authority if you place a little authority with them, nor forward anything beyond a point where it would involve the Institute, before it is presented at a full meeting. And, at any rate, nothing in this matter can assume any importance until it comes before our next semi-annual meeting. Contributions to the subject can therefore be sent to the Secretary, and I will bring them before the committee.

Meeting adjourned.

THE EXCURSIONS

At the close of the session Wednesday morning some of the members visited the chemical, engineering and physical laboratories of the University of Pennsylvania, thence to the Commercial Museum. The large majority, however, proceeded at once to the plant of Harrison Brothers & Co.

At the University Dr. Edgar F. Smith, the vice provost, received the visitors and himself conducted them through the chemical laboratories.

From the chemical laboratories the party proceeded to the mechanical and physical laboratories where, owing to the illness of Dr. Spangler, the plant was exhibited and methods discussed by his assistant.

Crossing over to the Commercial Museum of Philadelphia, which is happily located almost within the University grounds, the visitors found a unique institution. Dr. Wilson and his assistants made remarkably clear the enormous value and possibilities of the work the Museum is doing. Samples of almost every product of the Orient are on exhibition. In many cases large quantities are stored for the use of those who may desire to test or examine products, and an enormous mass of information and personal experience has been collected as to their methods of production,

manufacture and use, as well as the commercial methods, requirements, packages, etc., acceptable in the respective countries. Dr. Wilson most hospitably placed the facilities of his organization at the disposal of the Institute, saying that he would gladly furnish samples of such products to the members for comparison or test in any industry in which they might be interested. The value of his work is remarkably illustrated by the fact that federal departments at Washington turn to Dr. Wilson for information or securing samples of foreign manufacture.

About forty members and guests visited the Harrison Brothers' Chemical Works on the afternoon of December 8th. Shortly after arriving at the plant, lunch was served. For convenience, several parties were arranged, each in charge of a prominent and competent officer of the company.

The methods of manufacture of paints, red lead, white lead by the Carter process, nitric acid, sulphuric acid, both by the contact and chamber process and aluminium sulphate was shown.

The entire day Thursday was given to excursions along the river, for which purpose the fire tug *S. H. Ashbridge* was placed at the Institute's disposal by Mayor Reyburn. More than usual interest was found at the Torresdale Filtration Plant because of the extremely undesirable qualities of the Delaware River water for both power and potable use and the remarkable degree to which the difficulties are overcome.

The Wool Degreasing Plant of Erbin, Harding & Co., at Tacony, was of special interest as being the most recent of the two degreasing plants in the United States.

The very extensive plant of the Welsbach Light Co., was next visited.

At the plant of the Camden Coke Company many of the members were surprised not so much by the process as by the distribution of the gas. Few people realize perhaps that Camden is supplying gas for New Brunswick, N. J., 80 miles distant. Mr. Moore, the General Mamager and formerly President of the American Coke & Gas Construction Co., the engineer of the plant, gave the members a great deal of interesting and valuable detailed information, comparing this plant with others of later construction and pointing out resulting economies and advantages along the line of development.

The return by the *Ashbridge* was made according to schedule,

and the most interesting and profitable day completed by the dinner at the hotel.

Friday afternoon about forty members and guests visited one of the Trenton Potteries and the Hamilton Rubber Works at Trenton, N. J. At the pottery the entire process of making sanitary plumbing ware was inspected.

The remainder of the afternoon was spent in inspecting the Hamilton Rubber Works, where a large variety of rubber goods are manufactured. The process of reclaiming was inspected with great interest.

THE DINNER

The dinner was held at the Hotel Walton on Thursday evening. Members and guests to the number of forty were seated at a well-arranged and decorated table in one of the large dining halls of the hotel. Dr. Chas. F. McKenna of New York, the newly elected President, acted as toastmaster.

Mr. M. C. Whitaker of Gloucester, N. J., gave the first toast, on "The Chemical Engineer in the Development of American Industries." Mr. Whitaker gave tersely and forcibly his views of the needs of American industry and what part the chemical engineer was to take in their future development.

Prof. William P. Mason of Troy, N. Y., being called to answer to the toast "The Civil Engineer and the Chemical Engineer," showed how the chemical engineers could profit from the experience of the civil engineers.

Mr. Robert S. Perry, President of Harrison Bros. & Co., responded to the toast, "The Manufacturer and Chemical Engineer." He expressed his delight that he has found his gloomy forebodings at the birth of the Institute to have been entirely groundless, and now felt that the Institute was destined for a bright future. Particularly would this be so if the high standard of membership already established were sustained.

Dr. F. W. Frerichs of St. Louis next spoke on the subject, "The Institute in the West." He presented a most impressive statement of the conditions surrounding chemical industries in the Middle West. Dr. Samuel P. Sadtler then reviewed the history of the Institute under the subject, "What we Have Accomplished."

Dr. W. P. Wilson, Director of the Commercial Museum of Philadelphia, gave a valuable summary of the aims, the scope and the accomplishment of this great work which, though supported by Philadelphia merchants, is for the aid of American commerce in general, and is much used by the United States Government itself and very frequently appealed to by foreign governments. He gave a very cordial invitation to the members of the Institute to visit the museum and take advantage of any information obtainable there.

Dr. J. Takamine was called upon by the toastmaster, and in a very entertaining way described what Japan owed not only to American diplomacy, but to American industry and chemical technology.

CONSTITUTION

ARTICLE I.

NAME.

This organization shall be termed,

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

ARTICLE II.

OBJECTS.

The objects of this organization shall be:

To advance the cause of applied chemical science.

To give the profession of Chemical Engineers such standing before the community as will justify its recognition by Municipal, State, and National authorities in public works.

To raise the professional standard among Chemical Engineers, discouraging and prohibiting unprofessional conduct.

To coöperate with educational institutions for the improvement of the education of the men who are to enter this profession.

To encourage original work in chemical technology.

To promote pleasant acquaintance and social and professional intercourse among its members.

To publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity.

ARTICLE III.

MEMBERSHIP.

Section 1. (*Qualifications for Active Membership.*) Active membership shall consist of but one grade and shall require the following preparation and training:

All candidates must be not less than 30 years of age and must be proficient in chemistry and in some branch of engineering as applied to chemical problems, and must at the time of election be engaged actively in work involving the application of chemical principles to the arts. All candidates for admission to this Institute are expected to have *expert knowledge of at least one branch of applied chemistry.* and must fulfill one of the following requirements:

1. Candidates who hold no degree from an approved university or technical school must have had ten years' experience in chemical technology; five being in responsible charge of operations requiring the elaboration of raw materials, the design of machinery involving chemical processes, or the application of chemistry to industry.

2. Candidates who hold the degree of A. B. (Bachelor of Arts) from an approved university or technical school offering a four-year course must have had at least eight years of practical experience as outlined under No. 1.

3. Candidates who hold the degree of Ch. E. (Chemical Engineer), B. S. (Bachelor of Science), in Chemistry or Chemical Engineering, or E. E. (Electrical Engineer), C. E. (Civil Engineer), or M. E. (Mechanical Engineer), or equivalent degrees from an approved university or technical school offering at least a four-year course, must have had at least five years' practical experience as outlined under No. 1.

4. For candidates who in addition hold the degree of Ph. D. (Doctor of Philosophy) or Sc. D. (Doctor of Science) in Chemistry, the number of years required to earn the higher degree may be deducted from the number of years of experience required.

Section 2. (*Applications.*) All applications for membership must be made to the Secretary in writing, and shall embody a concise statement with dates of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Membership Committee. The applicant shall give the names of at least five members to whom he is personally known. Each of these shall be requested by the Secretary to certify to the training, experience, professional attainment, and standing of the applicant. On receiving a favorable report from at least three of these references, the applicant shall be eligible to recommendation by the Membership Committee.

Section 3. (*Election of Members.*) At stated periods the Secretary shall mail to the members a ballot containing a list of all applicants who have been recommended by the Membership Committee. This list shall contain a detailed statement of each applicant's career and the names of the members who have vouched for him. All ballots shall be returned to the Secretary not later than three weeks after the date of issue. The ballots shall be canvassed by the Membership Committee, who shall report to the Council, who shall then declare each applicant elected for whom at least ninety-five per cent. of all

ballots cast are in the affirmative. Provided, however, that any member voting in the negative may address a confidential letter to the Council, stating his objections to the candidate with evidence for the charges made. If the Council upon investigation considers such objections valid, they may declare an election void. A rejected candidate may make application again any time after one year. Persons elected to membership shall be notified at once by the Secretary. They must then subscribe to the rules of the Institute.

Section 4. (*Honorary Members.*) As the result of unusual ability and public recognition on the part of the industrial world, a person may, upon nomination of the Council and a vote of the Society at large, be made an Honorary Member, but at no time shall this number exceed five.

Section 5. (*Expulsions.*) For abuse or misuse of the privileges of the Institute or conduct unbecoming a member in the opinion of the Council, a two-thirds vote of the Council may expel any member of the Institute.

Section 6. (*Dues.*) The entrance fee shall be $15; Annual Dues $15. Provided, however, that no entrance fee shall be exacted until the membership shall reach 200.

Any member may anticipate his dues for life by paying in advance such a sum as would be demanded by any reputable insurance association to yield an annuity equal to the annual dues from the time of the agreement until death. Upon resignation, or expulsion, all money so provided is to become the property of the Institute. Any person joining the Institute after the middle of the fiscal year is required to pay one-half of the dues only for that year. Any person in arrears for three months shall be notified by the Secretary. For non-payment at the expiration of one-half year, a member forfeits the right to vote or to receive the notices of the Association until dues are paid in full. All members are considered as such unless actual resignations are formally presented and accepted with the full payment of dues. On account of extenuating circumstances, dues may be remitted to any member by a two-thirds vote of the Council.

ARTICLE IV.

OFFICERS.

Section 1. The officers of this Society shall be a President, three Vice-Presidents, a Secretary, a Treasurer, an Auditor, and nine Directors. The officers shall be elected at the annual meeting. The President shall serve one year, the Vice-Presidents for three years each.

and the Directors for three years each. The Secretary, Treasurer, and Auditor shall be elected for terms of one year each. At the first annual meeting one Vice-President shall be chosen for one year, one for two years, and one for three years. Three Directors shall be chosen for one year, three for two years, and three for three years. Thereafter, officers shall be chosen annually to serve full terms. The President, Vice-Presidents, Secretary, Treasurer, and Directors shall constitute the Council of the Institute. The President, Vice-Presidents, and Directors cannot be re-elected within the current twelve months from the expiration of term. The duties of office begin immediately after election and notification. An acceptance of office must be in writing addressed to the Secretary. Vacancies occurring in any office shall be filled by a majority vote of the Council for the unexpired term. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or the Institute.

Section 2. (*Election of Officers.*) After the election at which this Constitution is adopted, the election of officers shall be by letter ballot. The Secretary, at least eight (8) weeks prior to each annual meeting, shall send to every member of the Institute a blank nominating ballot upon which the member may make nominations for the officers and Directors to be elected at the coming annual meeting. The nominating ballot is then to be properly signed and transmitted to the Secretary not later than five (5) weeks prior to the annual meeting. It shall then become the duty of the Secretary to prepare and issue an official ballot upon which shall appear the names of all nominations for office or for Directors which shall have appeared upon at least ten (10) nominating ballots. The official ballots shall be mailed not later than three (3) weeks prior to the annual meeting, one to each member, who shall properly signify on it his choice for the various offices and Directors, and transmit it to the Secretary. At the annual meeting the President shall appoint tellers to whom the Secretary shall deliver all the ballots received by him unopened, and who shall count and announce the vote.

ARTICLE V.

COUNCIL.

The Council shall have supervision and care of all property of the organization, and shall conduct its affairs according to the Constitution and By-Laws. At each annual meeting it shall present a statement of its proceedings during the year. Eight members of the

Council called together by notice from the Secretary shall constitute a quorum, provided, however, that three members may be represented by proxy.

ARTICLE VI.

STANDING COMMITTEES.

The Council shall appoint the following committees:

1. FINANCE.
2. COMMITTEE ON MEETINGS.
3. PUBLICATIONS.
4. MEMBERSHIP.
5. LIBRARY.
6. HOUSE COMMITTEE.

FINANCE COMMITTEE.

The Finance Committee shall have charge of the financial affairs of the Institute. This committee must prepare the budget and approve all expenditures. The Chairman of the Committee may be the Auditor of the Institute.

MEMBERSHIP COMMITTEE.

The Membership Committee shall be constituted of fifteen members, ten of whom may vote by proxy at any meeting. To the Membership Committee all applications for membership shall be referred. It is the duty of this committee to see that no person is admitted to the organization who is not qualified.

COMMITTEE ON MEETINGS.

This committee shall have charge of all meetings of the organization and shall fix dates and places of meeting.

COMMITTEE ON PUBLICATIONS.

This committee shall look after the papers presented to the Institute. If considered expedient, any or all of these papers may be published and distributed to members.

LIBRARY COMMITTEE.

This committee shall have charge of all permanent records, books, papers, pamphlets, etc., and shall obtain and place on file a complete record of all patent literature in reference to chemical engineering.

HOUSE COMMITTEE.

This committee shall look after the social affairs of the Institute, fixing the time and place of entertainments.

ARTICLE VII.

MEETINGS.

The annual meeting of the Association shall be held in December, the exact date to be fixed by the Council.

This Institute shall be governed by its Constitution in conformity with the laws of the United States. All questions shall be decided by majority of votes cast. The Institute shall not be held responsible for opinions expressed in papers. The name or use of the Institute shall not be tolerated for any commercial purpose.

Upon the adoption of this Constitution officers shall be elected immediately to hold office until the election and installation of their successors.

ARTICLE VIII.

AMENDMENTS TO THE CONSTITUTION.

Any member may propose an amendment by addressing the Secretary. At the first regular meeting thereafter the subject shall be discussed, and if worthy, notice to vote on same shall be posted until the next regular meeting, and written copy of the notice shall be sent to each member. The proposed amendment shall then be discussed in open meeting and can be passed by two-thirds vote of all members of the Institute as the result of letter ballot.

BY-LAWS

ORDER OF BUSINESS.

REGULAR MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Reading of papers, discussion, and communications.
Adjournment.

ANNUAL MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Stated business.
Annual reports.
Election of officers.
Address of retiring President, etc.
Adjournment.

In all questions requiring parliamentary ruling not provided for by the Rules of the Institute, "Robert's Rules of Order" shall be the governing authority.

OFFICERS AND COMMITTEES FOR 1910

COUNCIL

Elected at Philadelphia meeting, December 8, 1909.

President,
CHAS. F. MCKENNA . . . . 50 Church St., New York city.

First Vice-President,
F. W. FRERICHS . . . . . St. Louis, Mo.

Second Vice-President,
EDWARD G. ACHESON, ... Niagara Falls, N. Y.

Third Vice-President,
EUGENE HAANEL, ... Ottawa, Ont., Can.

Secretary,
JOHN C OLSEN . . . . . Polytechnic Institute, Brooklyn, N. Y.

Treasurer,
WM. M. BOOTH . . . . . Dillaye Bldg., Syracuse, N. Y.

Auditor,
H. S. RENAUD * . . . . . 159 Front St., New York city.

DIRECTORS FOR ONE YEAR

ADAMSON, GEO. P. . . . . Easton, Pa.
WESSON, DAVID . . . . . 111 South Mountain Ave., Montclair, N. J.
GUDEMAN, EDWARD . . . . . Postal Tel. Bldg., Chicago, Ill.

DIRECTORS FOR TWO YEARS

BROWN, H. F. . . . . DuPont Bldg., Wilmington, Del.
REUTER, LUDWIG . . . . . Berkeley, Cal.
SMITH, THORN . . . . . Detroit, Mich.

DIRECTORS FOR THREE YEARS

GROSVENOR, WM. M. . . . . 1123 Broadway, New York.
MEADE, RICHARD K. . . . . 405 National Bank Bldg., Allentown, Pa.
SADTLER, SAMUEL P. . . . . 39 South 10th St., Philadelphia, Pa.

COMMITTEE ON PUBLICATIONS

MASON, WILLIAM P., Chairman . Troy, N. Y.
ANDREWS, LAUNCELOT W. . . 3731 Westminster Pl., St. Louis, Mo.
GROSVENOR, WM. M. . . . . 1123 Broadway, New York.
HART, EDWARD . . . . . Easton, Pa.
NEIL, JAMES M. . . . . 12 Woodlawn Ave., Toronto, Can.
OLSEN, J. C. . . . . Polytechnic Institute, Brooklyn, N. Y.
STILLMAN, JOHN M. . . . . Stanford Univ., California.

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* The Auditor is not a member of the Council.

MEMBERSHIP COMMITTEE

Langmuir, A. C., Chairman	9 Van Brunt St., Brooklyn, N. Y.
Adamson, Geo. P.	Easton, Pa.
Allen, Lucius E.	Box 22, Belleville, Ont., Can.
Barton, G. E.	419 High St., Millville, N. J.
Bassett, William H.	Torrington, Conn.
Bement, A.	Fisher Bldg., Chicago, Ill.
Dow, Alan W.	24 East 21st St., New York.
Frerichs, F. W.	3828 Westminster Pl., St. Louis, Mo.
Hollick, Herbert	General Chem. Co., Camden, N. J.
Kaufmann, H. M.	Mutual Chem. Co., Jersey City, N. J.
Marsh, C. W.	Niagara Falls, N. Y.
Olney, Louis A.	Lowell Textile School, Lowell, Mass
Renaud, Henry S.	159 Front St., New York city.
Robertson, Andrew	2 North 9th St., Richmond, Va.
Thompson, Gustave W.	129 York St., Brooklyn, N. Y.

COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Frerichs, F. W., Chairman	St. Louis, Mo.
Booth, Wm. M.	Syracuse, N. Y.
Rosengarten, Geo. D.	Philadelphia, Pa.
Veillon, A. A. L.	1800 South 2d St., St. Louis, Mo.
Wiechmann, F. G.	24 State St., New York.

COMMITTEE ON MEETINGS

Grosvenor, Wm. M., Chairman	1123 Broadway, New York.
Andrews, Launcelot W.	823 Brady St., Davenport, Ia.
Booth, Wm. M.	Dillaye Bldg., Syracuse, N. Y.
Langmuir, A. C.	9 Van Brunt St., Brooklyn, N. Y.
Meade, Richard K.	405 Nat. Bank Bldg., Allentown, Pa.
Olsen, J. C.	Polytechnic Inst., Brooklyn, N. Y.
Sadtler, Samuel S.	39 South 10th St., Philadelphia, Pa.

FINANCE COMMITTEE

Renaud, H. S., Chairman	159 Front St., New York.
Hart, Edward	Easton, Pa.
Adamson, Geo. P.	Easton, Pa.

COMMITTEE ON MEDAL

Booth, Wm. M., Chairman	Syracuse, N. Y.
Richards, J. W.	Lehigh Univ., South Bethlehem, Pa.
Robertson, Andrew	2 North 9th St., Richmond, Va.
Sadtler, Samuel P.	39 South 10th St., Philadelphia, Pa.

LIST OF MEMBERS, MAY, 1910

Honorary Member

CHANDLER, CHAS. F., Columbia University, New York city.

Active Members

ACHESON, EDWARD G., Niagara Falls, N. Y.
President International Acheson Graphite Co.

ADAMSON, GEORGE P., 233 Reeder St., Easton, Pa.
Vice-President and General Manager, The Baker and Adamson Chemical Co.

ALEXANDER, JEROME, 502 West 45th St., New York city.
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ALLEN, LUCIUS E., Box 22, Belleville, Ont., Can.
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ANDREWS, LAUNCELOT W., 823 Brady St., Davenport, Ia.
President Andrews Chemical Works.

ARNOLD, CHARLES E., 602 West 20th St., Wilmington, Del.
Chemical Engineer for the E. I. du Pont de Nemours Powder Co.

BAEKELAND, LEO H., Yonkers, N. Y.
Research Chemist and Chemical Engineer.

BAIN, J. WATSON, University of Toronto, Toronto, Can.
Associate Professor of Applied Chemistry.

BAKER, JOHN T., Phillipsburg, N. J.
President J. T. Baker Chemical Co.

BARTON, G. E., 419 High St., Millville, N. J.
In charge of Laboratory and Dept. Mfg. Glass, Whitall Tatum Co.

BASSETT, WILLIAM H., Torrington, Conn.
Metallurgist American Brass Co.

BEBIE, J., 1800 South 2d St., St. Louis, Mo.
Chemical Engineer Monsanto Chemical Works.

BECNEL, LEZIN A., 51 Arabella St., New Orleans, La., P. O. Box 390.
Chemical Engineer and Consulting Chemist.

BEHREND, OTTO F., Erie, Pa.
Vice-President and Treasurer Hammermill Paper Co.

BELDEN, ARTHUR WILLIAMS.
Engineer in charge, Technological Branch, U. S. Geological Survey, 40th and Butler Sts., Pittsburg, Pa.

BEMET, A., 2114 Fisher Building, Chicago, Ill.
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BJERREGAARD, A. P., 1311 East 92d St., Cleveland, Ohio.
Mfg. Chemist Canfield Oil Co., Cleveland, Ohio.

BOOTH, L. M., 136 Liberty St., N. Y.
President and Director, L. M. Booth Co., New York.

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Consulting Chemist and Engineer.

BOWER, WILLIAM H., 2815 Gray's Ferry Rd., Philadelphia, Pa.
First Vice-President of Henry Bower Chemical Mfg. Co.

BROOKS, PERCIVAL C., Hegewisch, Ill.
Foreman Silicate of Soda and Chloride of Zinc Depts., General Chemical Co., Hegewisch Station, Chicago, Ill.

BROWN, H. F., Room 915 du Pont Bldg., Wilmington, Del.
Chemical Director, Smokeless Powder Dept., E. I. du Pont de Nemours Powder Co.

CAMP, J. M., Duquesne, Pa.
Chemist and Chemical Engineer, Duquesne Plant, Carnegie Steel Co.

CAMPBELL, JOHN HAYES, 3847 W. Pine St., St. Louis, Mo. Chemical and Metallurgical Engineer, Fredericktown, Mo.

CARNELL, WILLIAM C., Bridesburg, Philadelphia, Pa.
Chemist for Chas. Lennig & Co.

CATLIN, CHARLES A., 133 Hope St., Providence, R. I.
Chief Chemist and a Director of the Rumford Chemical Works.

CHUTE, HARRY O., 197 Pearl St., New York. Chemical Engineer.

DAHLQUIST, CARL CHRISTIAN, 30 Church St., New York city.
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DAVOLL, DAVID L., Jr., Guantanamo, Cuba.
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DEAN, JOHN G., Exshaw, Alberta, Canada.
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Herf & Frerichs Chemical Co.

GIBBS, A. E., Wyandotte, Mich.
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GRETH, J. C. WM., Pittsburg, Pa.
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* Deceased.

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Secretary, The Midland Chemical Co.

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Chemist and Engineer of Tests, Union Pacific R. R. Co.

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HOLLICK, HERBERT, The Robeson, Camden, N. J.
Supt. Moro Phillips and U. S. Wks. of General Chemical Co.

HORN, DAVID WILBUR, Bryn Mawr, Pa. Consulting Chemist.

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* Deceased.

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MINER, H. S., Gloucester City, N. J.
Chief Chemist Welsbach Light Co.

MINOR, JOHN C., Jr., Saratoga Springs, N. Y.
Manager, New York Carbonic Acid Co.

MOECHEL, J. R., 1110–1112 Wyandotte St., Kansas City, Mo.
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Professor of Metallurgy Lehigh University; Secretary American Electrochemical Society; President Electrochemical Publishing Co.

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SADTLER, SAMUEL S., 39 South 10th St., Philadelphia, Pa.
Samuel P. Sadtler & Son.

SHARPLES, STEPHEN P., 26 Broad St., Boston, Mass.
Analytical and Consulting Chemical Engineer and Assayer.

SIMMONS, W. H., Fenton, Mich. Supt. Badger Portland Cement Co.

SIMPSON, EDWARD H., Westside Ave., Jersey City, N. J.
Manager Arlington plant of the Mutual Chemical Company of America.

SMITH, FRANK CLEMES, Sault Ste. Marie, Ont., Can.
Gen. Mgr. Superior Copper Co., Ltd.

SMITH, FRANCIS PITT, 24 East 21st St., New York city.
Member of the firm of Dow & Smith, Chemical Engineers.

SMITH, THEODORE E., 54 Hudson Place, Weehawken, N. J.
Chief Chemist and Manager Lard and Oil Depts., Halstead & Co., Jersey City.

SMITH, THORN, 125 Langley Ave., Detroit, Mich.
Diack & Smith, Consulting Chemists.

STILLMAN, JOHN MAXSON, Stanford Univ., Cal. Professor of Chemistry.

TAKAMINE, JOKICHI, 520 West 173d St., New York city.
Consulting Chemist for Parke-Davis & Co., Detroit, Mich.

TAYLOR, EDWARD R., Penn Yan, N. Y. Manufacturing Chemist.

TAYLOR, JOHN, Leggett Bldg., St. Louis, Mo.
Manager St. Louis Portland Cement Works of the Union Sand and Material Co.

TEAS, WILLIAM H., Ridgway, Pa.
General Supt. U. S. Leather and Allied Companies.

THOMPSON, GUSTAVE W., 60 So. Portland Ave., Brooklyn, N. Y.
Chief Chemist, National Lead Co.

THORP, FRANK H., Boston, Mass.
Ass't Prof. Industrial Chemistry, Mass. Inst. Tech.

TOCH, MAXIMILIAN, 320 Fifth Ave, New York city.
Member of firm of Toch Bros.

TRAUTWEIN, A. P., Carbondale, Pa. Pres. Carbondale Instrument Co.

TYSON, GEORGE N., 2815 Gray's Ferry Road, Philadelphia, Pa.
Supt. for the Henry Bower Chemical Manufacturing Company.

VEILLON, A. A. L., 1800 South 2d St., St. Louis, Mo.
Vice-President and Works Manager Monsanto Chemical Works.

WATSON, JOHN R., 214 8th St., W. Hutchinson, Kansas.
Cudahy Packing Company.

WESSON, DAVID, 111 South Mountain Ave., Montclair, N. J.
Manager Tech. Dept. Southern Cotton Oil Co., 24 Broad St., New York city.

WHITAKER, M. C., Gloucester, N. J. Gen. Supt. Welsbach Co.

WHITFIELD, J. EDWARD, 406 Locust St., Philadelphia, Pa.
Member of the firm of Booth, Garrett & Blair.

WIECHMANN, FERDINAND G., 24 State St., New York city.
Consulting Chemical Engineer.

ZWINGENBERGER, O. K., 106 Fulton St., New York city.
Chemical Engineer.

ADDRESSES AND PAPERS

READ BEFORE THE INSTITUTE

THE CENTERING OF GREAT INDUSTRIES IN THE NEW YORK METROPOLITAN DISTRICT

By CHARLES F. McKENNA, Ph.D.

Read at the Brooklyn Meeting, June 24, 1909

If on a map of Greater New York and its environs we were to draw a line from the city of Yonkers on the Hudson in New York to the city of Paterson on the Passaic in New Jersey, and then extend it southerly to the city of Newark, to Elizabeth, to Perth Amboy, around Staten Island, thence to and around the easterly boundaries of the borough of Queens and The Bronx to the city of Yonkers again, we should have circumscribed a territory approximately 700 square miles in area, whose great natural and acquired advantages for the economical manufacture of the greatest variety of materials have brought about most happy and satisfactory results for commerce and technology.

In this territory will be found located the great sugar refineries of Yonkers, Edgewater, Jersey City, Brooklyn and Greenpoint; the silk and woolen mills of Paterson, Passaic and Hoboken; the metal smelting works of Newark, Irvington, Perth Amboy, Carteret, Staten Island, Bayonne and Laurel Hill; the corn works of Shadyside; the chemical works of Lodi, Shadyside, Newark, Perth Amboy, Bayonne, Staten Island, New York city, Bushwick and Greenpoint; the jute mills and fiber works of Brooklyn; the linen and cotton thread works of Paterson and Newark; the lead and white lead works and linseed oil plants of Staten Island and Brooklyn; the paint and varnish works of Newark, Jersey City, Long Island City and Brooklyn; the lard refineries of Guttenberg, Jersey City and New York city; the cotton oil refineries of Guttenberg; the great soap works of Babbitt, New Jersey and New York and Jersey City and Staten Island; the glue and fertilizer industry of Newark and Barren Island, and lastly the great mineral oil refineries of Brooklyn, Edgewater, Bayonne, Bayway and Greenpoint.

It has not been my principal view to refer to the other very large manufacturing interests for which the district is famous,

such as the production of clothing and of the great variety of general articles of wood, leather, metal or whatsoever material; or to the manufactures solely intended for supplying utilities to the district, such as gas making; I mean rather to consider the great fundamental industries in which raw material is treated in a large way for the supply of the world's markets with staples. Those listed thus make a very impressive array. Some general figures about them make an astonishing showing.

Eighty per cent of the 6,000,000,000 pounds of refined sugar used in the United States is refined here; the concern which refines 80 per cent of the petroleum in the United States has here five of the largest of its twenty refineries, and another concern one refinery; the silk mills of the district, including throwing, weaving and dyeing works, are more than 60 per cent of all in the country, and produce more than $60,000,000 worth of goods, and so on through most of the industries which seem almost peculiar to the district, so concentrated is the country's production therein.

The foreign commerce figures of this and certain other large ports are striking:

Total Imports, Fiscal Year 1907

New York city	$853,696,952
Boston	124,432,977
Philadelphia	79,869,942
Baltimore	37,774,305
San Francisco	54,094,570
New Orleans	46,046,772
All other ports	238,505,907
	$1,434,421,425

Total Exports, Fiscal Year 1907

New York city	$646,270,674
Galveston	236,277,727
New Orleans	169,897,311
Boston	99,820,742
Philadelphia	94,542,966
All other ports	636,908,614
	$1,853,718,034

But the census figures for all manufacturing industries hereabouts also contain some statistical truths of importance.

INDUSTRIES OF METROPOLITAN DISTRICT

COMPARATIVE RETURNS FOR 1900 AND 1905 FROM MUNICIPALITIES WITH POPULATION EXCEEDING 8000

	Number of Establishments.		Aggregate Value of Products	
	1900.	1905.	1900.	1905.
New York city	12,243	20,839	$1,172,870,261	$1,526,523,006
Yonkers	107	105	17,303,690	33,548,088
	19,350	20,944	$1,190,173,951	$1,560,071,094
New York State	35,957	37,194	$1,891,830,872	$2,488,345,579
Bayonne	63	58	38,601,429	60,633,761
Bloomfield	39	33	3,370,924	4,645,483
Elizabeth	141	124	22,861,375	29,300,801
Hackensack	21	23	782,232	1,488,358
Harrison	41	41	6,086,477	8,408,924
Hoboken	194	279	10,483,079	14,077,305
Jersey City	536	628	72,929,690	75,740,934
Kearney	16	11	1,607,002	4,427,904
Montclair	23	19	663,592	621,145
Newark	1,573	1,600	112,728,045	150,055,227
Orange	74	66	2,995,688	6,150,635
East Orange	22	17	2,086,910	2,326,552
Passaic	70	95	12,804,805	22,782,725
Paterson	487	513	48,502,044	54,673,083
Perth Amboy	47	53	14,061,072	34,800,402
Union	57	77	3,403,136	3,512,451
West Hoboken	65	95	4,769,436	5,947,267
Metropolitan dist. in New Jersey	3,469	3,732	358,736,936	479,592,957
New Jersey	6,415	7,010	553,005,684	774,399,025

SUMMARY

Metropolitan dist., New York	19,350	20,944	$1,190,173,951	$1,560,071,094
Metropolitan dist. New Jersey	3,501	3,781	361,174,370	483,165,091
Metropolitan dist., total	22,851	24,725	$1,551,348,321	$2,043,236,185
Rest of United States	184,711	191,537	$9,859,772,801	$12,758,910,902
Total of United States	207,562	216,262	$11,411,121,122	$14,802,147,087

From the above table it will be seen that the States of New York and New Jersey, which contain about one-eighth of the population of the United States, produce within their bounds nearly a quarter of the aggregate national manufactures. Of the three and a quarter billions made in these two States, about two billions fall to the share of the Metropolitan District, or about one-seventh of the entire production of the United States, while its population may be estimated at about one-twelfth of the total. The importance of the district as a factor in our national industrial economy is thus amply illustrated. With its two billion annual product of varied manufactures, the Metropolitan District far outstrips the other general manufacturing cities in the country; Chicago being next in importance with one billion dollars; Philadelphia and Camden following with six hundred and twenty-five million, and Boston with the neighboring cities showing about three hundred and sixty millions.

The manufacturing capital in the whole of the United States was, in 1905, about thirteen billion dollars, or 86 per cent of the annual product. The proportion shown for the Metropolitan District was about 72 per cent of the annual product. Thus the Metropolitan District gets a larger return on capital invested than the rest of the country.

Cost of Labor

By the census figures the amount of wages paid in the entire country on the product of $14,802,000,000 in 1905 was $2,611,000,000, or about 18 per cent. A separate figure for the Metropolitan District was about 16 per cent. This can be laid to high value of machine output.

Natural Causes for Growth

It is well for the citizens of the metropolis to understand why these industries have been attracted to it, how they can be held and encouraged to increase and how others can be induced to settle within the same area.

The location of great industries sometimes moves the world almost as much as political and great popular movements. The cotton of Manchester, the iron of Cleveland, the soda of Newcastle in resisting competition of place and of process, by being firmly rooted, have affected the destinies of England beyond estimation.

The fight of Pittsburg against the Lake District, the South and the seaboard will result, though a strife among brothers, in the absolute domination of the United States in the iron and steel trade of the world; while the contest between the cotton mills of New England against the advancing front of the Southern mills has brought about in the former such attention to detail and economy, and such application of higher technical skill trained in special schools for that very emergency that the result is the protection of enormous investments, the perfection of products and a stop to the loss of trade.

In seeking for natural or historical reasons to explain the industrial development of the New York Metropolitan District, we find in the first place that while this fair section of our planet has both hills and plains, it is washed and serrated by a generous supply of waterways, that these in turn are deep and that they terminate in bays of large extent, discharging voluminously into the ocean.

A properly drawn map will also show a great network of rails approaching the center, running along the banks of these waterways, crossing them above, below, connecting and interconnecting. When to those natural advantages we add that of a commanding position as a port of entry, and one where articles of export can be most favorably taken on, we see that these are the overwhelming influences causing the growth. Civic pride directing the mighty forces to co-operate here has not at all been the agency for good that we might imagine—the great city has grown rather in spite of a deficiency of such pride. The historic significance of the early selection of this port for entry by the trans-oceanic vessel lines, the genius of De Witt Clinton, the parallel powers of Alexander Hamilton, have frequently been recorded, but notwithstanding the existence of chambers of commerce, boards of trade and merchants' associations, few grand conceptions similar to Clinton's creation of the Erie Canal and Hamilton's foundation of a city on the Passaic and the utilization of the water power of that river, or similar to the introduction of the Croton water system into New York city in 1842 have been formed or brought to completion.

Lack of perception between the States and among numerous municipalities that their interests were so intertwined as to be identical have hampered great undertakings leading to expansion

of manufactures; and in many ways when these did not operate as inhibiting agents the evils of petty political maneuvering did.

The writer proposes to show that if the great Metropolitan District just described could be included in a commercial zone to be covered by treaty in which the community of interest would be thoroughly recognized, for the improvement of waterways, raising of flooded land areas, the erection of docks, increase of water supply, tapping and introduction from a distance of large supplies of fuel, gas or electricity, protection of certain areas against land exploitation in order that housing may be sanitary, salubrious and secure for the laboring man; all of these could be brought about without waiting for the hapazard development that comes with the urgency of demand. An enlightened and broad-minded consideration of the rights of the ten million dwellers to be in this territory ought now to be taken up by those highest in authority and most able to bring about the good.

Let us consider how these great works came to grow. Many of them, such as the sugar business and chemical works, were in the very earliest history of the city used to meet the local demand of their vicinity. The first sugar refiners were the confectioners. The first lard refining was in the slaughter houses. The possibility of shipping by the Erie Canal and the bringing of hard coal by rail and water determined that the refineries, paint works and chemical works could increase, and the supplying of the outside world began. The greatest factor of influence besides those already mentioned was undoubtedly the draining of the Pennsylvania oil fields into this center by means of a pipe line 400 miles in length.

The offensive character of some of these businesses, and the necessity for securing large areas of cheaper land than city lots gradually caused the establishment of factories in the meadow lands of the surrounding river valleys, and in many cases the works that had removed to a desolate spot became the center and cause of a small city itself. Then improvements were made in processes which made even some of the most offensive innocuous and not in such wise undesirable.

Sites

We find now the following situation as regards site and position. The Hudson River from Yonkers down to and opposite Riverside Drive has been taken up for park or ornamental purposes

which will exclude factories in the future. The city generally has such extraordinary demand for its docks for steamship and general city purposes that very little manufacturing will in the future be done immediately on Manhattan Island's waterfront. Brooklyn, Astoria and a part of The Bronx shore will continue to attract manufacturers. South Brooklyn is particularly advantageously situated, although the land areas are not so large. Staten Island, from the point of view of deep water frontage and large inland areas is an ideal situation and promises to continue the great growth which has been going on for a score of years. Perth Amboy, Bayonne, Elizabeth and Newark are rapidly assuming positions of importance in the establishment of large units of production of manufactures. In Jersey City, Hoboken, Weehawken are some old-established water-side sites improved nearly to their limits. Passaic and Paterson are desirable locations for manufacture of articles susceptible of carrying heavier charges for handling, and calling for a large force of contented skilled labor. The meadows skirting the shores of the Hackensack, Newark Bay and Passaic River have been left to the last, because we considered it one of the most important of the local areas, and the one which will call in the future for the application of the most far-sighted principles of development. These meadows extend from Elizabeth to Hackensack and are of the general width of four miles and are about eighteen miles in length. There is an area of 27,000 acres involved. There are twelve important lines of railway crossing them. The improvement by filling and utilizing as solid land areas of this great and almost unused territory is a dream which has fascinated many engineers and economists, who see on the one side of it the great metropolitan city and on the other side other large cities growing towards one another until they appear to meet and form another unit which could almost be called a metropolis.

Admitting that one of the great reasons for the development of Manhattan Island was its beautiful situation, washed by swiftly flowing and broad streams on two sides, one finds in these other two rivers, the Hackensack and the Passaic, the promise of great advantage if only the low-lying bordering acres could be properly prepared for industry. Such an improvement was proposed in 1896 (Geological Survey of New Jersey, Report of State Geologist for 1896) by C. C. Vermeule, whose plans included a system of embankment and subsequent removal of the water by pumping.

This has never been carried out on exactly the same plan as proposed by Vermeule, but to some extent certain portions of these meadows have been improved by depositing upon them river mud and sand dredged by hydraulic dredges. The result is that at present an area of several hundred acres has been prepared for use, none of which has yet, however, been improved by factory buildings.

The city of Newark interested itself in securing the deepening of the channel in Newark Bay to about the center line of the city. This improvement has just been consummated. The same city is also at work on a project of excavating further channels and a canal system bordered by bulkheads behind which the dredged material will be deposited, thus reclaiming an area of three or four thousand acres.

Fuel and Power

The great element of advantage to New York in the past has been its proximity to the anthracite coal fields of eastern Pennsylvania. This valuable fuel was supplied in amounts of extraordinary tonnage, and at prices which for a great many years during the early development of manufactures was extremely low. The appearance of the specter of extinction of its valuable deposits has been one of the elements along with the high labor costs and high freight rates to bring about high prices for this coal delivered in New York city. The price has continued to increase till now steam sizes in large lots are from $2.50 to $3.00 per ton. Bituminous coal is coming more and more into use in the outlying parts where smoke consuming may not be so strongly enforced. The prices of this coal are on a par with anthracite. Of both kinds of coal the factory demand on New York harbor points is about 2,500,000 gross tons annually.

With such fuel charges the cost of steam power would have risen to a damaging level were it not for a coincident improvement in boiler and steam engine practice. The need of large volumes of water for condensing has not been felt by any of the factories located on the tidal streams and bays. In the great railway power houses increased efficiency is being reported, and it seems as if extensive manufacturing establishments ought to acquire whatever of these advantages are not due to regularity of output and steadiness of load. The great losses from imperfect combustion and

from unburned coal still continue to be viewed calmly by numbers of managers.

In the future new sources of power will probably be placed at their command, and inasmuch as the largest field for such power will be where manufactures are most concentrated, it is easy to see what could be promised for the district of New York and Newark and the meadows territory lying between. In the first place we could consider the advantages of power gas. If gas were manufactured for a market at forty cents, the residuals being produced on a large scale, the consumption for gas engines would warrant the establishment of such a works in a very large unit in the most desirable place in the center of the greatest consuming territory. With the improvements in gas engines, with direct connected electric generators, the installation of large units intended for the production of power by power gas is very promising.

Another source of cheaper fuel and power might be sought for in the utilization of the culm banks of the coal mines in the anthracite district, but whether this culm could be carried or floated to New York, or whether it should be gasified near the point of largest supply and the gas piped to New York, does not make such an important question, inasmuch as culm would appear to be an unreliable source and itself rising in value where it is produced.

The advance in producer-gas practice, so well known to you all, points the way clearly for economy to those works managers who can use the product to most advantage; and the adaptation of the producer principle to ordinary furnaces promises still further economy of fuel. Oil as fuel should continue to excite interest even at this point, four and five hundred miles from the original source of supply of crude oil. The reason for this lies in the fact of an interesting change in the mineral-oil industry coming about through the rapid introduction of power vehicles and power boats. The great demand for gasolene caused by these has brought about such changes in refining that a larger yield of fuel oil is now obtained than formerly. As a consequence its value is as low as 2¾c. per gallon. The Appalachian, the Lima and the mid-continental fields, with pipe lines to New York, and producing over 50,000,000 barrels of oil, from which 20 to 25 per cent of fuel oil can be obtained, certainly gives promise of a steadiness of supply, even if the demand should grow great.

The most fascinating promise of new power for this district comes from the hopes of the utilization of certain water powers. The nearest is the power of the Passaic River. It is proposed to establish reservoirs along this stream so that the present flow can be better regulated and power obtained over long intervals, but at its best the maximum of power obtainable from this stream is only 12,000 horse power, and it is already owned by the Society for the Establishment of Useful Manufactures founded by Alexander Hamilton and controlled by the East Jersey Water Company.

The next most valuable source is to be found in the Delaware River in New York State; the next after that the water powers of the upper Hudson River.

In an admirable report of the New York State Water Supply Commission on Water Storage and Power Developments, 1909, these are particularly well described.

In the case of the Delaware water power, the following appears in the special report of the engineer, in speaking of the improvement of the Delaware River between Cannonsville and Port Jervis, which could furnish 40,000 to 50,000 constant mechanical horsepower: "This 40,000 to 50,000 continuous hydraulic horse power will generate, at 95 per cent efficiency of electrical machinery, from 28,500 to 36,600 kilowatts, which, distributed under a 50 per cent load factor, and 85 per cent efficiency in transformation and transmission, would deliver in ordinary working hours a maximum of 65,000 to 81,000 electrical horse power at the consumer's end." He says: "There is at present no nearby demand for anything like this enormous amount of power. The only adequate market from which returns might be expected is to be found in the thriving manufacturing cities of eastern New Jersey at an average distance of ninety miles. The industrial activity in many of the places within fifteen miles of Jersey City, together with the rapid growth in population, and the constant extension of electric railways throughout this district, hold out attractive possibilities for the sale of electric power."

But the most promising scheme is the development of the upper Hudson between Troy and Hadley, where horse power is already developed, but where by systematic improvement 196,000 total horse power could be developed, and as the distance from New York is not at all prohibitive for economical transmission it would seem as if it would materialize. A very powerful agency

for bringing this about in the future will be the concurrent improvement in the hydrographic situation which goes with this power improvement, namely, the prevention of floods with all of their accumulated evils.

Given a supply of electrical horse-power in this Metropolitan District under consideration, we could easily see how manufacturing for export of every variety of substances which can now be made the product of the electrolytic vat or the electric furnace will bring still larger industrial interests. And this mode of application of the current is the most promising one for the justification of these distant hydro-electric plants; inasmuch as the demand at an electro-metallurgical works is not as exacting as that of an electric railway, because the volume of current demanded in the former permits of long-distance transmission with less line and transformation losses.

If the water powers of the Passaic, the Delaware and the Hudson were improved and utilized thus in and near New York city the combined power supply and present manufacturing development of Niagara Falls, N. Y., and of Lowell, Lawrence and Holyoke, Mass., could be duplicated here and leave many thousands horse-power to spare. The politico-economic effect of such a concentration would be as interesting a study as that of its technological consequence.

Water Supply

But a great want in the future will always be water supply. There are few subjects which give the technical factory manager operating here more concern than this. Shortage of supply, corrosion of boilers, incrustation, or large water bills—some or all of these things afflict all but the most favored.

The point of view of the governing authorities in considering water supply is always of course first the question of the securing of a potable supply. But the factory manager gives attention also to the questions of qualities for his purposes and of cost. A potable water supply would not always be as desirable for, let us say, a dye house or a bleachery, as one which would not meet the views of the sanitarian for some pathological reason, but which really furnished a good and peculiarly desirable supply. But fortunately most often the most potable water of the large supplies is also equally the most desirable for technical use. The great

bugbear for the large steam users is the cost of water, and if this could be reduced the advantage would be considerable and tend to prolong the contest of the steam engine against the gas engine. Water bills of $30,000 and $40,000 a year for a single factory are not uncommon in the vicinity of New York.

In the district we have under consideration there is a great variety of water supplied.

Yonkers obtains its supply mostly from wells and a small river. The present supply of The Bronx is obtained from the Bronx and Byram Rivers, and partly from the inflowing Croton supply. The latter is the great source of supply to the city. Brooklyn is obliged to rely upon the water pumped from beneath the surface of Long Island, although at present estopped from drawing from Suffolk County. Staten Island is in a very serious situation. The State of New Jersey forbids the diversion of stream waters from that State into New York and consequently Staten Island. Staten Island has some local water from springs and wells, and many manufacturers are using water from wells sunk by themselves. Almost all of these yield water of excessive hardness unsatisfactory for both domestic and technical use. The supply of water from Brooklyn to Staten Island would be difficult in an engineering way by reason of the crossing of the Narrows, and moreover it would be some years before Brooklyn shall have any to spare. It was thought a supply of water might yet come to Staten Island from New Jersey, sent by pipe lines from water works pumping only from wells, which had been said to be a diversion allowable as distinct from that of stream water; but a decision just rendered adverse to this view in the Supreme Court of that State a few days ago again puts an embarrassing question before New York city in doing justice to Staten Island. If this admirable territory is to advance by the location of large industries, a water survey and a water project must be at once provided for.

Almost equally urgent is the consideration of the water supply of all that part of the territory we are considering which lies entirely in New Jersey. Its population will now grow rapidly by reason of tunnel construction accomplished and bridge construction promised; the growth will be out of proportion to that of the last decade; the consumption of water for power and technical uses will grow as the borders of these bays and streams and the filled-in areas of the meadows are taken up by large industries and

the ones already established. Some of the water companies already supplying portions of this territory are close to the limit of their resources, and the largest of them could hardly expect to meet the demand of the future. Much of the supply is drawn from wells which will be abandoned as communities grow closer to them, thus adding to the demand on the larger supplies.

A solution of the difficulty for New York in its Staten Island supply, and for New Jersey in its eastern cities supply, is to be found in the eradication, by treaty, for this if for no other purpose, of the State line of demarcation and the treatment of the water question as of common concern to all. If the States and the counties recognize no lines of distinction, the following would be the sources to be availed of in the future as a universal system:

Underground Long Island (Queens, Nassau and Suffolk Counties).

The Bronx and Byram Rivers.

Yonkers wells.

Staten Island wells.

Croton system.

Hudson River at Hyde Park.

Catskill and Esopus system.

Passaic River system.

Rockaway River system.

Hackensack River system.

Pequannock Valley system of Newark.

Perth Amboy wells.

If Brooklyn should draw all that is needed from Long Island, if Staten Island be allowed to draw from New Jersey and in return for this concession New York permit its Catskill line to be tapped at Cornwall for the supply of that part of the territory under consideration lying on the same side of the Hudson, all groups and consuming centers and intercommunicating fields would be supplied with the maximum of economy, the minimum of further outlay and the maximum of technical and sanitary purity. But a cry of horror will go up from the New York city taxpayer when he is told of a proposition that contemplates giving advantage to residents of New Jersey of what shall have been acquired by him at a cost beyond his willingness at present to sit down and calculate. But this is just what he should do for his own financial salvation.

The Catskill water project has been unwarranted by the facts. In the first place the estimates of the population of the future and of the per capita consumption were reached in a faulty manner. They are both too high. The diagrams submitted by the City of New York Board of Water Supply giving the consumption and population, Manhattan and The Bronx, 1900 to 1940, show how gratuitous was the assumption of the persistence for thirty years of the present rate of increase.

Secondly, the resistance of Suffolk County to draft of water from its subterranean territory could have been overcome by offers to purchase the right, thus resulting in such an income for that county that they would have been rich beyond the dreams of avaricious counties. The county's watershed could yield over two hundred million gallons per day, and it could not use one-tenth of that in its most likely crowded condition.

Thirdly, the storage capacity of the Croton system can be still further increased. The continued overflow of the Croton, amounting to as much as five hundred million gallons per day for the entire period of this spring, shows that the surplus that could be availed of will continue to be an important factor in delaying the drawing down of the utmost utilized storage capacity.

Fourthly, the restriction of waste is no negligible factor, and could be introduced at any time that need was shown for it; at any rate, long before the high figure of 195 gallons per head should ever be approached.

Lastly, even admitting that some of these arguments would have tended to create dangerous unconcern in the minds of citizens, we have yet to face the fact that the new supply could have and should have been drawn from the Hudson River above the influence of tidewater.

I quote from Freeman, New York Water Supply, 1900, page 10.

"By taking water from the Hudson River at Poughkeepsie and filtering it, and by constructing storage reservoirs in the Adirondacks to let down water whenever in extreme drought there was any sign of brackishness in the Hudson water at Poughkeepsie, and then by filtering this Hudson water as Poughkeepsie has done for its own supply from the Hudson for twenty-seven years, or as Albany is doing to-day, New York city can obtain any desired quantity even up to 800,000,000 gallons per day at a cost, including interest, maintenance, depreciation and sinking fund to pay

off all costs of construction in forty years, for water delivered at the city limits at three hundred feet above the sea level, less than $50.00 per million gallons."

Also from the Burr, Herring, Freeman Commission on Additional Water Supply, 1904, page 43:

"This committee is of the opinion that by adopting proper precautions and also reinforcing the flow in time of drought from large storage reservoirs under the city's control to be established in the Adirondacks, the water taken from the river near Hyde Park could, by filtration, be rendered potable and entirely safe for drinking, domestic and industrial uses."

Although further on (pages 54 to 55), this project meets with unfavorable comment for fear of "mediocrity of management" in the pumping plant; yet at page 64 it is praised as "by far the most practicable and economical plan of taking water from the Hudson River for purposes of additional supply."

In the prosecution of the Catskill project many difficulties have been met with, and very large additions to the estimated cost are now admittedly necessary. The difficulty of crossing the Hudson River has become increasingly great. The point at which it is now said the crossing is to be made is at Cornwall, about fifty miles from the city. This aqueduct will thus have been brought to within forty miles of the center of the district we are considering, or about sixty miles from Staten Island. To tap it there to go to New Jersey and Staten Island through the trans-Hudson River Valleys is to open a market at once for surplus goods whose production has cost too much to admit of neglecting any sale. Moreover, if this line could be put into commission several years before the completed line across the river the financial advantage will not be inconsiderable. Instead thereafter of expecting the private water companies of New Jersey to continue the erection of new reservoirs and lines to keep up with the increase of demand, cooperate with them and feed water into their mains whether by sale or after condemnation. In other words, let the people get the best water and the most water on the best terms.

Let the whole territory be considered as a unit of interest. Every factory established in eastern New Jersey is an asset for New York city and every dweller there a contributor to the wealth of New York city. Then when a population shall have grown up which consumes all of the present supplies and the Catskill supply,

we shall still have the Hudson filtered water to draw upon and the Suffolk County supply. For twenty-five years before that time shall have arrived we will have been drawing a large income from the surplus Catskill water. We shall have been supplying to Staten Island in the most practical way what is difficult to supply across the Narrows, and we shall have been aiding to develop a fringe of New Jersey which, by almost every right, is practically our own city.

Materials Supply

There are many considerations not touched upon before which point to the correctness of any view which sees a great technical industrial future for the enlarged metropolis. Such would be the excellent supply of materials—raw materials—coming by rail and by inland water and from over sea, and general materials for supplies and repair being quickly obtained. This latter is a source of economy and makes for ease of mind of the factory manager. Such also is the favorable market for skilled and unskilled labor. Another great advantage is the ease of importation and the facilitation of customs business. Manufacturing in bond for export should develop largely in such a district.

We might give a moment's consideration to the observation of how peculiarly certain industries have passed the district by. We have for instance practically no iron-producing industry. The last blast furnace, that at Secaucus on the Meadows, went out of blast a few years ago. An old-established rolling mill for structural material at Paterson went into the hands of a receiver about two years ago. Another of pretentious size and new eqiupment, designed to manufacture open-hearth steel and roll structural shapes, met with a like fate during the panic. A wire-rod mill making its own open-hearth steel at Astoria several years ago went the same way. Several crucible-steel works, however, are operating and prospering continuously. But there can be little question, and some good authorities interested in other districts have admitted it, that a blast-furnace plant and a steel works for rail or structural shapes could, under proper conditions, be successful in this position. These conditions would appear to be the use of Cuban ore, as well as of Adirondack, Orange County and New Jersey ores, the manufacture of by-product coke, the utilization of the gases of both coke ovens and blast furnace and a continued

supply of scrap. It is possible that the reduction of the duty on iron ore may help to bring such a project to realization. At any rate, we are almost certain to see, with the introduction of electric power the establishment of a considerable number of electrical steel furnaces.

Paper manufacture does not exist, if we except certain paper board manufactories, and it is not likely to be established. There is no manufacture of cement, and there is not to be any, though we may see clinker ground on a large scale and distributed in the surrounding country in bulk.

With this review we may dismiss our subject, but not without expressing a hope of seeing industrial happiness here continue and increase. Because that man is most blessed who is industrious, that city is the happiest which has the greatest proportion of contented workers. Our best monuments will not be pleasure palaces but healthful factories, comfortable homes, cheerful and beautiful buildings called for by the highest aspirations of a people living by toil but neither exhausted nor hopeless.

Therefore to lead this district to its best development is an accomplishment worthy of genius of the highest abilities in constructive statesmanship and practical economics.

Conclusions

Enough has been said to indicate the truth of the following propositions:

1. The territory described and recognized as the great Metropolitan District is destined to be a most interesting technological center by reason of the establishment within it of the largest works in the world treating raw materials for the production of staples.

2. Its advancement would be more rapid if certain extensive improvements were made under some form of convention eliminating the disadvantages of separate State control.

3. A universal project for water supply is the most important of these improvements.

4. Reclamation of large sunken areas adjacent to deep water to adapt them to normal uses of land is the next most important improvement.

5. Introduction of electric power from the nearest large hydraulic conservation works in both States is an improvement which gives promise of most extraordinary advantages, particularly for

electro-chemical and electro-metallurigcal development similar to that at Niagara Falls.

Wm. M. Booth:

I have listened to this paper with great pleasure. It is of particular interest to manufacturers and of very great interest to chemical engineers, for it relates to the use of coal and of water in connection with the production of power and industry. At Syracuse, we depend very largely upon Niagara power, brought over 150 miles. It drives the street cars and lights our homes. As fast as we get accustomed to this it is proposed to extend its use. You are not more remote than this from an immense source of power north of you. I believe that you are about 140 miles from Albany, and you would not have to go very much farther. I was told by Prof. Wallace Johnson in connection with water power, that in the Adirondacks we have available five hundred thousand horse power without seriously interfering with the scenic beauty of the park system. So that it seems perfectly possible that New York city can use this enormous power for the industries that have so fortunately clustered around the lower end of the Hudson River. The question of water is, in my estimation, of primary importance to every manufacturer, and pure, soft water is sure to command a great premium at this point; that is, in connection with the industries of lower New York State. A man who spoke with authority, now dead, said that New York State would cry some day for water. And this is not unique for New York State. It will be true everywhere as manufacturing increases in volume. In my paper of mid-year before the Institute I mentioned the enormous increase of steam power in this country. The increase has been from a few millions to 14,000,000 horse power in a comparatively short time—a period of about thirty-five years. Where the coal is to come from to take care of this is a serious matter. Mr. Whitney of Massachusetts, as some of you probably know, proposed to pipe gas the whole length of that State, making the gas probably at Boston, and carrying it to the different cities. He said that it would help the manufacturers of Massachusetts very largely. For some reason or other the project was never realized. It certainly would be a wonderful feature if, like oil, gas could be brought into New York city from some point in New Jersey, or from some point more

accessible, to be sold here at a reasonable price. In conjunction, then with the points taken up in Dr. McKenna's paper with reference to producer gas, gas engines and power, and soft water supply for factory use, an aggressive campaign should be instituted towards the utilization of the natural resources of the State.

A. C. Langmuir:

Can you tell us why Staten Island has such a scant water supply, while Flatbush, with its big population, has still an ample water supply?

Dr. McKenna:

I imagine the answer must be found in the location of Flatbush. Flatbush stands upon an entire bed of sand gravel, which is, for some curious reason, always tapable, and this is so in almost any part of Long Island. In Staten Island, on the other hand, the ground is largely broken up by masses of igneous rocks. It is a broken geological mass. The supply of water is unreliable, and the water obtained does not give satisfaction in most cases. Particularly along the shores the water is very hard. Much of the water is supplied by water companies, and is obtained from certain lakes, reinforced by wells. These have recently been purchased, to be taken over by New York city. The purchasers after paying a high price for the water have generally put a penalty on each degree of hardness, I believe. At any rate the degree of hardness is a factor in reducing the price paid for the water. I understand from residents and others that the public service is quite hard, and a great many manufacturers who have examined the water from wells have found that quite hard. A good supply is not tapped continuously from any point for any great deal of time.

THE CHEMICAL INDUSTRIES OF AMERICA

By CHARLES E. MUNROE, Professor of Chemistry,
George Washington University

Read at the Philadelphia Meeting, Dec. 8, 1909

The topic which you have done me the honor to invite me to address you upon appears on first consideration quite specific, but investigation shows that this is not quite the case. Thus we find the popular idea of a chemical industry to be one producing acids, alkalies, salts, explosives, fertilizers, dyestuffs and extracts, pigments, distillation products and elementary substances like bromine, phosphorus, sodium and others, and the officials of the U.S. Census Bureau in 1880 in fixing a classification, styled in the various censuses "Chemical Production" or "Chemicals and Allied Products," adopted this popular view.

In discussing this, I have said, (1)* "A reason for the variation in the industries included at the different censuses is found in the very general and indefinite title used, for in the strictest technical sense every material thing is a chemical, and accordingly every industry in which the materials used undergo a chemical change in the process of manufacture, as in the smelting of iron from its ores or the production of leather from a hide, may be considered as a chemical industry. It is evident that if this view of the significance of the title were taken, "Chemicals and Allied Products" would properly cover every manufacture except those like furniture-making, machine construction, or textiles, in which the material remains unchanged in composition during the manufacture, but is turned, or cast, or woven into other shapes. The popular idea of the term limits its application, but admits as chemical industries the manufacture of gunpowder, fertilizers, and similar mixtures, whose ingredients undergo no chemical change during the process of compounding the mixtures. It

* Bull. 92: Census of 1905, page 9, by Charles E. Munroe.

thus became necessary to decide arbitrarily upon the industries to be included. Those so included at the census of 1905 may be divided into the following classes: Sulphuric, nitric, mixed and other acids; sodas; potashes; alums; coal-tar products; cyanides; wood distillation; fertilizers; bleaching materials; chemicals produced by the aid of electricity; dyestuffs; tanning materials; paints and varnishes; explosives; plastics; essential oils; compressed and liquefied gases; fine chemicals; general chemicals." These were consequently divided into nineteen different classes which were given separate treatment. The combined statistics for these classes for the censuses of 1900 and 1905 are set forth in the following table, the statistics of these two censuses only being compared because they alone dealt with the same materials:

TABLE I

CHEMICALS AND ALLIED PRODUCTS OF UNITED STATES, 1900 AND 1905

	Establishments. Number.	Wage Earners. Number.	Total Wages. $	Materials Used. Cost $	Products Value. $
1905	1,786	59,198	29,515,863	176,400,680	282,169,216
1900	1,691	46,700	21,783,335	124,018,044	202,506,076
Increase	95	12,498	7,732,528	52,382,636	79,663,140
Per cent of incr.	5.6	26.8	35.5	42.2	39.3

From Table I it is observed that there was an increase in every item enumerated, but that, not only was the actual increase in the number of establishments less than that of any other item, as was to be expected, but that the percentage increase was less. This indicates that the growth of these industries was rather by increased production of existing establishments than by the creation of new ones. In fact in a more detailed analysis it was found that in some industries the number of establishments had actually decreased, though each of the other items, as enumerated in Table I, showed an increase.

The greater percentage increase in wages over that of the percentage increase in wage earners shows that the lot of the latter was improved and possibly indicates that a better class of labor was employed and, since the percentage increase in the number

of salaried officials for these establishments was 29.6, while the percentage increase in salaries was but 32.4, it is obvious that the wage earners fared, on the whole, better than the salaried officials.

A wholesome feature to be observed is that while the increase in the number of men employed was 12,104, the increase in the number of women employed was but 413, while there was a decrease of over 10 per cent in the number of children employed. I speak of this condition as a wholesome one because, outside of the clerical and perhaps analytical work, the duties to be performed in these establishments is essentially man's work.

The greater percentage increase in the cost of materials used as compared with the percentage increase in the value of the products shows the growing necessity of intelligent and careful management and skillful workmanship to prevent waste and to increase yields. This is emphasized by examination of the additional item of miscellaneous expenses which, while less in the total than any of the values given in Table I, showed an increase of 77.2 per cent.

As indicated, the Census classification of "Chemicals and Allied Products" which gave the data just discussed, is a purely empirical one, and it deals with but a very few of the true chemical manufactures of the United States. It is not possible to derive from the returns, of the various industries as taken, the data for an exact scientific classification such as has been referred to above. Yet, in order to arrive at a better conception of the application of chemistry in manufacturing industries and its magnitude, we may follow such a scheme of classification as that employed in many chemical technologies, though here again we meet with the difficulties common to classification and we are compelled to include in our data some of the products of purely physical processes, either because these processes are operated collaterally with, or are related to, the predominating chemical processes, or else because the products are closely associated with the chemical products. In assembling this data it should be said that in order to compare the data of the different epochs one must first eliminate from the data of 1900 the returns for neighborhood industries, because the census of 1905 was a factory census and considered only the results of manufacture as carried out in factories, and not solely for consumption at the point where manufactured, as is generally the case with neighborhood industries. The results of this treatment are set forth in Table II.

TABLE II

CHEMICAL INDUSTRIES OF THE UNITED STATES, 1880 TO 1905

	1905.	1900.	1890.	1880.
Establishments:				
Number.....	56,580	53,567	40,451	34,804
Wage earners:				
Average number	1,107,714	943,166	677,123	490,776
Wages:				
Total, ...$	575,635,257	438,404,062	305,884,278	176,227,726
Materials used:				
Cost .....$	2,933,660,817	2,215,162,767	1,247,239,582	924,573,773
Products:				
Value .....$	4,716,490,371	3,628,641,475	2,152,490,514	1,357,503,213

Table II, imperfect though it be both in the industries it includes and those it omits, gives a better conception of the actual magnitude of the industries in which chemical transformations play a part, and which are therefore really chemical industries, than Table I does and in so doing it shows the value of the products for 1905 alone to be nearly 17-fold greater than is set forth in Table I. The increase is easily accounted for by noting that items such as soap, with a product valued at over $68,000,000; glass over $79,000,000; illuminating gas over $125,000,000; dairy products over $168,000,000; refined petroleum over $175,000,000; paper and wood pulp over $188,000,000; bread and other bakery products over $269,000,000; sugar and molasses over $277,000,000; vinous, malt and distilled liquors over $340,000,000; smelting and refining of copper, lead and zinc over $461,000,000; iron and steel over $905,000,000, and many other items have been added to those embraced in Table I.

The simple enumeration of these items indicates how incomplete the statistics usually presented as those of the chemical industries are and how insufficient the popular conception of the chemical industries is. Yet even the data of Table II do not present the case in full, since all agricultural products, amounting in value in 1900 to $4,717,069,973, are really the results of chemical processes and are therefore the products of chemical industries, although not factory products.

As with Table I, so with Table II, the deductions are more readily drawn by observation of the increase and percentages of

increase for each item at the various epochs. These have therefore been ascertained and are set forth in Table III.

TABLE III

INCREASES AND PERCENTAGES OF INCREASES FOR CHEMICAL INDUSTRIES

	1900 to 1905.		1890 to 1900.		1880 to 1890.	
	Increase.	Per Cent.	Increase.	Per Cent.	Increase	Per Cent.
Establishments, number .	3,013	5.6	13,116	32.4	5,587	16.0
Wage earners, average No.	164,548	17.4	266,143	39.3	186,347	38.0
Wages	$137,231,195	31.3	$132,519,784	43.3	$129,656,552	73.6
Materials used, cost	718,498,053	32.4	967,923,182	77.7	322,665,809	34.9
Products, value.	1,087,848,896	30.0	1,476,150,961	68.6	795,987,221	58.6

Considering now the data of Table II and more particularly the increases and percentages of increase set forth for each epoch in Table III, while keeping firmly in mind the fact that we are here dealing with two 10-year periods and one 5-year period, it is again to be noted that both the actual and percentage increases in the number of establishments are the smallest of all the various increases set forth and that increase for this item for the 1900–1905 period is not only actually less than for 1890–1900 and 1880–1890, as should be expected, but is proportionately less, thus emphasizing what has been deduced from Table I as to the increased production of existing establishments.

Likewise the consideration of the data for this larger number of industries extending over a greater length of time shows that not only is the percentage increase in wages nearly as great at the census 1905 as those for cost of materials and greater than the value of products, but that, while the proportionate increase in the number of wage earners for the 1900–1905 period is less than that of 1890–1900, the proportionate gain in wages is greater. In fact, all statistics point to markedly improved conditions for the wage earner in the chemical industries, and to his increased participation in the income from the enterprise. This fact is one to be reckoned on by the chemical engineer in making up his estimate for the cost of a projected enterprise which it is proposed to install.

The statistics of Tables II and III, on the other hand, do not so markedly support the deductions drawn from Table I as to the

increase in cost of materials used when compared with the increase in the value of the products in 1900–1905. However, when we consider the larger items included in these later statistics, such as iron and steel; smelting and refining of copper, lead and zinc and others we may each of us recall a variety of labor-saving devices which have been invented and introduced for cheapening the cost of production and handling of the raw materials of these industries, and that the inventions have increased in number and perfection with the growth in magnitude of these industries.

An increase in cost of materials is in conformity with the long-recognized natural law of supply and demand. A modification of this law through which labor may get its fair share of increase and capital may get its fair share of increase while the actual cost may not proportionately be increased has been brought about in recent times through the increase in the magnitude of the unit of demand, or in other terms the quantity handled. As stated, this has to an extent been rendered possible by the introduction of labor-saving machinery, much of which has been invented in this country.

But in my opinion, and if I read aright the reports of foreign commentators on our chemical industries, in their opinions, the chief modification in the operation of this law has been made in this country through the development of "team work," though the writers style it organization or systemization.

Entering on my fortieth consecutive year of college teaching, I might, from what has been so persistently dinned into my ears, have been led to believe that "team work" originated in the minds of the college youths who flock to Franklin Field or to the Harvard Stadium. Sitting on the bleachers with practical politicians and presidents, I might be led to suppose that "team work" was an invention of the professional athlete. As a fact the idea of "team work" is a very old one and military in its essence and original application. It is embodied in our national motto. It is commemorated in the "Charge of the Light Brigade." But this older practice, while greatly promoting efficiency, demanded such unreasoning subordination that the private soldier was properly looked upon as but "food for powder," and when this system was introduced into the factory the operator became but "a cog in the machine."

The modification in this plan of "team work" which has been

developed to such advantage in the industrial plants of this country has come through a recognition of the great value of individuality and the necessity for its preservation and development, and it has been demonstrated that the higher the intelligence of the individuals who merge their entities with that of their fellows in a common purpose, and the more complete their comprehension of the means used and the end sought the more successful is the result whether gauged by the quality, or the quantity, or the cost of the output. I am happy to say that the chemist has destroyed the older military idea, even in the army, for by his invention of high-powered smokeless powder he has compelled armies to fight in open order, so that each individual must exercise his own powers in attack and defense, and be trained to take the initiative in case of necessity.

Naturally the application of labor-saving machinery and of "team work" is most readily made and yields most efficient results in the production, transportation and handling of the raw materials of our larger industries, and it is in these that we find the smaller proportionate increase in the cost of materials.

American industries, in which the chemical industries are included, have signalized themselves by the introduction of standards, by the introduction of interchangeable parts into mechanisms, by the wide application of labor-saving machinery and by the use of "team work." Yet notwithstanding the vast resources of this country, their ease of access, and the cheapening, by methods such as described, of many of the costs of production, the cost of "living," not only here but throughout the civilized world, has steadily increased, and I attribute this largely to the work of the chemist.

At St. Louis, in 1904, I said, "Technical chemistry, then, invades the domains of economics, of politics, and of diplomacy. A striking example of its effects in economies and politics is found in the settlement of the silver question. Gold is a most widely diffused metal. It has, for instance, been shown by assayers at the U. S. Mint at Philadelphia that if the gold in the clay of the bricks of which the buildings of the Quaker City are built could be brought to the surface, the fronts would all be gilded. In the past our processes for the isolation of this metal have been so costly that only the richer ores would bear treatment. Large bodies of low-grade ores which have been discovered and mountains of tailings carrying values were looked upon as worthless, while

enormous quantities of copper, lead, and other metals containing gold were sent into the market to be devoted to common uses, because the cost of separation was greater than the value of the separated products. Eight years ago, when the "silver question" was made the national issue, while the orators were declaiming from the stump, the chemists were quietly working at the problem in their laboratories and factories. Manhe's process for bessemerizing copper ores was combined with the electrolytic refining of the product, so that even traces of gold were economically recovered, while the cyanide processes, such as the MacArthur-Forrest, the Siemens-Halske, the Pelatan-Clerici, and others for the extraction and recovery of gold from low-grade ores and tailings, were successfully worked out and put into practical operation to such effect that by the cyanide processes alone gold to the value of $7,917,129 was recovered in the United States in 1902, which is more than was ever won throughout the whole world by all methods in any one year up to 1661, and probably up to 1701. The data for other purposes are not at hand for 1902, but the returns for 1900 show that gold to the value of $88,985,218 was recovered in the treatment of lead and copper ores in the United States, of which $56,566,971 worth was recovered in refining. It has but recently been publicly proclaimed in this city of St. Louis, that the "silver question" is settled, and it is settled, but it was settled largely through the efforts of the technical chemists and metallurgist."

With the improvements in methods and diminution in cost of extraction the Pactilean stream has continued to flow in steadily increasing volume* until the flood of gold has become so great that its purchasing power has become markedly reduced, and costs, measured in terms of gold, have become markedly greater. With this condition well determined the chemist has again stepped in to increase the cost of living by requiring the application of costly

* PRODUCTION OF GOLD

Year.	World's Production.		Production in the United States.	
	Fine Ounces.	Value.	Fine Ounces.	Value.
1878	5,761,114	$119,092,800	2,476,800	$51,200,000
1888	5,330,775	110,196,900	1,004,841	43,175,000
1898	13,877,806	286,879,700	3,118,398	64,463,000
1908	21,378,481	441,932,200	4,574,349	94,560,000

methods of inspection of foods, drugs and other articles of consumption; by demanding the elimination of preservatives which permitted the abundance of the harvest being kept until time of need; or the plethora of one locality being sent to the land smitten with leanness; by insisting on the introduction of expensive sanitary arrangements. Pure food laws are the vogue, and all the other needs of man are becoming the subject of special legislation, some wise, but much otherwise. It would prove an interesting exhibit if a statistician were to assemble the actual costs in the administration and execution of these laws in this country alone during the past five years.

I speak with earnestness because I have repeatedly been a participant in these movements, and am even now engaged in an analogous humanitarian enterprise, and I know that a certain result of all such endeavors to improve the lot of man is to put the community to an increased expense.

Having confessed myself, and having found my profession guilty, as charged, I now assert that a chief duty of our profession is to determine methods by which the income may be increased or the costs of living in the land decreased, or preferably both, and I urge as a first measure the advocacy of the policy of preventing any material from leaving the country until it has passed through all processes of manufacture of which it is capable. The meaning of this is evident on inspection of the Exports of Domestic Merchandise (Table IV) prepared by the U. S. Bureau of Statistics, where we find that in 1908 over 885 million dollars' worth, or 48.19 per cent of the total exports, consisted of cotton, breadstuffs, meat and dairy products, and coal, much of which had not undergone any degree of manufacture whatever. All this food should have been elaborated in this country into brain and brawn, and the coal made to yield its energy, and then should have been expended here in manufacture. We should further have put into manufactured form the raw materials of other lands.

Inspecting on the other, the table of Imports of Merchandise (Table V) prepared by the U. S. Bureau of Statistics, we find that in 1908 but a little over 210 million dollars' worth, or 17.87 per cent of our imports, consisted specifically of unmanufactured materials, such as silk, hides and skins, India rubber and gutta percha, wool, cotton, copper, lead and iron ores, and briquettes, which would properly go into manufactures here.

We sit back glorying in our country, its wide extent, its rich resources, its teeming millions of independent and self-respecting people; and yet after our fleet has circumnavigated the globe we continue to sacrifice the fertility of our soils to the support of older civilizations and remain content, while ranging ourselves with those nations that live solely on their primary resources, since the "balance of trade" is in our favor. But we as chemists know that this condition cannot last. We know that the average fertility of our soil has been growing steadily less and that only by following sound scientific practice can the fertility of the impoverished soil be restored.

The utilization of the soil as a chemical factory is but one of the problems with which the chemist has to deal. That which appeals most nearly to us as chemical engineers is the item that appears as second in magnitude in the Table of Imports of Merchandise and which has held this second place for years, namely "Chemicals, drugs and dyes," for this category embraces those substances commonly known as chemicals, or the products of the "black art." In 1908 we imported $73,237,033 worth of this class of materials, or 6.13 per cent of our total imports. While we exported but $20,873,155 worth, or 1.14 per cent of our total exports. There was therefore a balance of $52,363,878 against us in this item in which the chemical engineers of this country are most nearly concerned. It is true that among these imports are upwards of $15,000,000 worth of crude drugs and dyewoods, and quantities of other crude material, but there are many million dollars' worth of substances included here that should have been manufactured in this country. Attention need only to be called to the acids imported to a value of over $1,300,000 to emphasize this fact, for while we are seeking an outlet for our sawdust, we find in this list nearly 9,000,000 pounds of oxalic acid. Or attention might be called to the more than $7,000,000 worth of coal-tar products and preparations, not medicinal. Had this been accomplished there is little doubt that our exports of such substances would also have been large. And what is true of the industries commonly called chemical would equally apply to those larger chemical industries not included in the common category.

Another policy we should follow is the promotion of chemical manufactures throughout a larger portion of our great territory. For this purpose, I have prepared Table VI, showing by states the

Table IV

VALUES OF EXPORTS OF DOMESTIC MERCHANDISE, BY PRINCIPAL ARTICLES AND CLASSES, IN ORDER OF MAGNITUDE IN 1908, DURING THE YEARS ENDING JUNE 30, 1902-1908

Order of Magnitude, 1908.	Articles.	1902	1903	1904	1905	1906	1907	1908	
								Value.	Per Cent of Total.
		Dollars.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	
1	Cotton, unmanufactured	290,651,819	316,180,429	370,811,246	379,965,014	401,005,921	481,277,797	437,788,202	23.86
2	Breadstuffs	213,134,344	221,242,285	149,050,378	107,732,910	186,468,901	184,120,702	215,260,588	11.73
3	Meat and dairy products	199,861,378	179,839,714	176,027,586	169,998,873	210,990,065	202,392,508	192,802,708	10.51
4	Iron and steel, and manufactures of	98,552,562	96,642,467	111,948,586	134,728,363	160,984,985	181,530,871	183,982,182	10.03
5	Copper, and manufactures of	43,820,070	40,594,613	58,119,006	87,564,009	83,178,035	96,600,698	105,872,711	5.77
6	Mineral oils	72,302,822	67,253,533	79,060,469	79,793,222	84,241,327	84,855,715	104,116,440	5.67
7	Wood, and manufactures of	47,779,848	57,743,535	65,428,417	58,002,977	69,080,394	83,349,575	81,521,305	4.44
8	Leather, and manufactures of	29,798,323	31,617,389	33,980,615	37,936,745	40,642,858	45,476,969	40,688,619	2.22
9	Tobacco, and manufactures of	32,772,849	40,444,689	34,683,531	35,491,019	34,218,847	39,113,011	39,463,679	2.15
10	Coal	20,765,461	21,206,498	27,820,323	29,158,322	28,216,376	34,727,762	39,355,759	2.15
11	Animals	44,871,684	34,781,193	47,977,875	46,728,281	49,139,568	41,203,080	34,101,289	1.86
12	Cotton, manufactures of	32,108,362	32,216,304	22,403,713	49,666,080	52,944,033	32,305,412	25,177,758	1.37
13	Agricultural implements	16,286,740	21,006,622	22,749,635	20,721,741	24,554,427	26,936,456	24,344,398	1.33
14	Cars, carriages, etc	9,872,516	10,499,195	10,936,618	10,610,437	17,788,425	20,513,407	22,072,902	1.20
15	Naval stores	11,733,562	12,918,708	16,145,222	16,106,643	20,075,585	21,686,752	21,641,599	1.18
16	Oil cake and oil cake meal *	19,779,142	19,743,711	16,899,257	21,498,085	23,386,218	25,738,471	21,064,974	1.15
17	Chemicals, drugs, dyes, and medicines	13,626,837	14,150,493	15,065,682	16,595,523	19,155,989	20,373,036	20,873,155	1.14
18	Vegetable oil	15,308,633	16,234,362	12,618,381	16,632,232	15,906,031	19,550,514	19,633,967	1.07
19	Fruits and nuts	8,719,344	18,057,677	20,678,665	15,606,586	15,274,158	17,588,432	14,338,864	0.78
20	Instruments for scientific purposes	5,389,476	7,130,508	8,297,723	8,172,980	10,887,774	13,661,455	11,578,010	0.63
21	Fertilizers	6,256,035	6,724,301	7,112,512	7,620,886	8,686,965	8,596,711	10,970,931	0.59
22	Paraffin and paraffin wax	8,858,844	9,411,294	8,859,964	7,789,160	8,808,245	9,030,992	8,740,929	0.48
23	Seeds	8,027,824	9,455,283	2,583,325	2,557,747	8,912,662	10,094,609	8,683,688	0.47
24	Paper, and manufactures of	7,312,030	7,180,014	7,543,728	8,238,088	9,536,065	9,856,733	8,064,706	0.44

25	Furs and fur skins	5,030,204	6,181,115	5,422,945	6,599,222	8,002,282	7,139,221	7,712,890	0.42
26	India rubber, manufactures of	4,032,100	4,675,157	5,148,950	5,508,664	6,543,735	7,428,714	7,573,570	0.41
27	Fibers, vegetable, etc., manufactures of	4,575,219	5,290,948	6,414,636	6,766,809	8,157,211	8,308,112	7,225,798	0.39
28	Books, maps, engravings, etc.	3,997,977	4,442,053	4,347,304	4,844,100	5,839,452	5,813,107	6,107,053	0.33
29	Grease, grease scraps, etc.	2,610,925	2,926,565	3,311,777	3,710,907	4,138,333	5,473,623	5,762,709	0.31
30	Fish	6,563,199	6,717,274	7,857,041	6,527,863	7,559,178	5,530,856	5,685,916	0.31
31	Household and personal effects	2,570,309	2,652,787	2,615,076	3,146,969	3,595,128	3,928,946	4,782,436	0.26
32	Coffee, green	3,209,946	3,295,968	3,050,943	1,966,107	3,483,238	4,692,137	4,314,020	0.24
33	Sugar, molasses, and confectionery	3,237,329	3,104,653	3,522,805	4,131,707	4,526,334	3,973,360	4,068,357	0.22
34	Paints, pigments, and colors	2,096,379	2,350,937	2,756,581	3,126,317	3,773,064	3,931,899	4,001,824	0.22
35	Vegetables	2,546,287	2,543,488	2,603,374	3,200,800	3,567,127	4,007,833	3,895,294	0.21
36	Explosives	2,062,381	2,454,510	2,441,596	2,559,837	3,568,038	4,082,402	3,705,517	0.20
37	Brass, and manufactures of	1,930,810	2,000,432	2,557,484	3,025,764	3,474,981	4,580,455	3,701,871	0.20
38	Soap	1,630,938	2,452,777	2,499,933	2,670,231	2,781,179	3,806,097	3,407,220	0.19
39	Musical instruments	3,694,143	3,381,509	3,230,982	3,144,787	3,168,052	3,256,063	3,371,521	0.18
40	Hops	1,550,657	1,909,951	2,116,180	4,480,666	3,125,843	3,531,772	2,963,167	0.16
41	Nickel, nickel oxide, and matte	1,190,606	864,221	940,558	3,196,622	3,240,544	3,218,862	2,948,058	0.16
42	Clocks and watches and parts of	2,144,490	2,133,529	2,281,195	2,316,414	2,598,441	3,169,272	2,848,725	0.16
43	Coke	1,720,457	1,912,459	2,223,233	2,228,442	2,435,604	3,013,088	2,718,385	0.15
44	Glucose and grape sugar	2,319,286	2,460,022	2,949,545	3,206,794	3,489,192	3,017,527	2,540,640	0.14
45	Glass and glassware	1,960,106	2,150,699	1,978,481	2,252,799	2,433,904	2,604,717	2,505,417	0.14
46	Wool, manufactures of	1,512,457	1,722,128	1,987,938	2,035,054	2,119,518	2,239,106	2,219,815	0.12
47	Lamps, chandeliers, etc.	963,638	1,133,290	1,502,888	1,579,125	1,954,091	1,875,869	1,827,216	0.10
48	Spirits, distilled	2,073,273	1,990,091	1,691,467	1,968,767	1,525,225	1,827,757	1,816,287	0.10
49	Zinc, and manufactures of	2,017,191	2,346,629	1,710,211	3,085,245	2,780,199	2,143,574	1,606,032	0.09
50	Hay	2,580,022	828,483	1,052,705	1,089,505	1,116,307	976,287	1,463,010	0.08
51	Marble, stone, and manufactures of	1,761,696	1,465,244	1,589,790	1,283,219	1,466,561	1,433,123	1,248,996	0.07
52	Starch	656,705	832,943	1,340,282	1,430,572	1,490,797	1,426,465	1,142,054	0.06
53	Malt liquor	1,290,062	1,178,740	854,119	1,012,808	1,116,776	1,215,340	1,020,172	0.06
	All other articles	23,761,904	22,557,283	25,770,532	30,732,482	30,998,594	35,784,782	38,463,024	2.10
	Total	1,355,481,861	1,392,231,302	1,135,179,017	1,491,744,641	1,717,953,382	1,853,718,034	1,834,786,357	100.00

* Corn oil cake not included.

Table V

IMPORTS OF MERCHANDISE, BY PRINCIPAL ARTICLES AND CLASSES, YEARS ENDING JUNE 30, 1902–1908

Order of Magnitude, 1908.	Articles.	1902	1903	1904	1905	1906	1907	1908	
								Value.	Per Cent of Total.
		Dollars.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	
1	Sugar	55,001,097	72,088,973	71,915,753	97,045,449	85,460,088	92,806,253	80,258,147	6.72
2	Chemicals, drugs, and dyes	57,723,622	64,351,199	65,294,558	64,779,559	74,477,137	82,997,914	73,237,033	6.13
3	Cotton, manufactures of	44,460,126	52,462,755	49,524,246	48,919,936	63,043,322	73,704,636	68,379,781	5.72
4	Coffee	70,982,155	59,200,749	69,551,799	84,654,062	73,256,134	78,231,902	67,688,106	5.67
5	Silk, unmanufactured	42,635,351	50,011,050	46,100,500	61,040,053	54,080,504	71,411,899	64,546,993	5.40
6	Hides and skins	58,011,168	58,031,613	52,006,070	64,764,146	83,882,167	83,206,545	54,770,136	4.59
7	Fibers, vegetable, etc., manufactures of	39,036,364	39,334,521	40,308,837	40,125,406	51,437,581	67,422,557	54,407,572	4.56
8	Wood, and manufactures of	24,445,599	28,746,271	26,984,353	29,564,323	36,532,706	42,969,941	43,527,982	3.64
9	India rubber and gutta-percha, crude	25,052,977	31,004,541	41,049,434	50,729,873	46,035,685	60,206,418	37,753,266	3.16
10	Fruits and nuts	21,480,525	23,726,636	24,435,854	25,937,456	28,915,747	35,867,160	37,354,742	3.13
11	Fibers, vegetable, etc, unmanufactured	31,545,962	34,462,513	37,814,285	38,118,071	39,360,290	42,239,358	35,493,083	2.97
12	Silk, manufactures of	32,640,242	35,903,552	31,973,680	32,614,540	32,910,590	38,053,251	32,717,068	2.74
13	Iron and steel, manufactures of	27,180,247	51,617,312	27,028,312	23,510,164	29,053,987	40,587,805	27,607,909	2.31
14	Tobacco, and manufactures of	17,706,493	20,579,120	20,073,346	22,145,846	26,590,706	30,192,375	27,267,913	2.28
15	Tin, in bars, blocks, and pigs	19,461,850	23,618,802	21,486,311	23,378,471	30,932,998	38,117,459	25,295,061	2.12
16	Copper, manufactures of	10,968,948	17,505,247	18,215,442	19,942,511	25,835,502	39,428,687	24,462,663	2.05
17	Wool, unmanufactured	17,711,788	22,152,961	24,813,591	46,225,558	39,068,372	41,534,028	23,664,938	1.98
18	Spirits, wines, and malt liquors	15,246,640	17,171,617	16,662,702	17,052,323	19,257,590	22,104,235	20,771,804	1.74
19	Wool, manufactures of	17,384,463	19,546,385	17,733,788	17,893,663	23,080,683	22,321,460	19,387,978	1.62
20	Oils	9,300,198	12,283,957	11,179,442	11,593,520	13,723,948	17,068,777	18,292,393	1.53
21	Furs, and manufactures of	15,623,601	15,301,912	14,763,002	18,306,302	21,855,082	21,884,034	15,918,149	1.33
22	Diamonds and other precious stones	23,348,225	31,479,223	22,964,119	33,313,931	40,247,010	42,278,901	16,642,634	1.39
23	Articles, the growth, etc., of the United States, returned	5,815,628	7,170,573	9,899,470	9,079,124	11,134,912	11,833,983	16,599,766	1.39
24	Tea	9,390,128	15,659,229	18,229,310	16,230,858	14,580,878	13,915,544	16,309,870	1.37
25	Cocoa, crude, and leaves and shells of	6,656,504	7,820,087	8,873,709	8,577,649	8,697,515	13,376,562	14,257,250	1.19

26	Cotton, unmanufactured	11,712,170	10,892,591	8,541,510	9,414,750	10,879,592	19,930,988	14,172,241	1.19
27	Leather, and manufactures of	11,317,785	11,294,167	11,100,215	11,666,233	15,140,926	20,393,533	14,127,347	1.18
28	Earthen, stone, and china ware	9,680,156	10,512,052	12,005,014	11,659,723	12,877,528	13,706,790	13,427,969	1.12
29	Fish	8,527,097	8,035,583	9,889,097	10,498,076	11,607,002	12,335,988	12,292,770	1.03
30	Paper, and manufactures of	4,223,125	4,733,036	5,319,086	5,623,638	6,998,761	10,727,885	12,223,058	1.02
31	Meat and dairy products	3,510,696	4,703,536	4,197,466	4,253,414	5,117,054	6,768,432	8,877,183	0.74
32	Vegetables	7,039,835	4,581,355	7,008,602	3,983,272	5,092,932	5,728,472	8,289,068	0.69
33	Toys	4,023,670	4,232,074	4,977,389	4,964,457	5,887,863	6,993,561	7,206,423	0.60
34	Breadstuffs	2,580,295	3,023,160	3,247,503	6,557,347	4,513,667	5,892,968	7,138,214	0.60
35	Copper ore	14,003,840	3,385,524	3,466,381	4,892,961	6,727,861	8,296,328	7,057,080	0.59
36	Metal, and manufactures of, not elsewhere specified	6,223,383	7,057,202	7,092,125	7,050,118	7,888,565	10,325,446	6,768,637	0.57
37	Glass and glassware	6,205,052	7,255,879	6,583,168	5,948,839	7,507,823	7,596,631	6,570,123	0.55
38	Seeds	3,252,152	2,831,279	3,587,469	3,457,619	5,388,043	6,404,776	6,371,470	0.53
39	Books, maps, engravings, and other printed matter	4,133,215	4,323,938	4,529,187	4,589,858	5,599,948	6,451,309	6,036,693	0.51
40	Coal, bituminous	5,310,450	10,562,185	5,043,824	3,713,748	4,367,750	4,184,541	5,123,862	0.43
41	Fertilizers	2,426,758	3,100,276	3,503,726	4,524,700	4,446,360	5,341,430	4,970,461	0.42
42	Hats, bonnets, and hoods, and materials for	3,050,478	3,871,278	3,963,043	4,379,473	4,571,184	6,820,259	4,852,548	0.41
43	Rice	2,926,921	3,061,473	3,073,430	2,010,966	3,082,203	4,392,146	4,798,553	0.40
44	Animals	4,624,531	4,533,845	3,129,609	3,337,454	3,914,382	4,344,282	4,777,459	0.40
45	Household and personal effects	2,934,244	2,856,007	3,040,523	3,203,384	3,941,875	3,835,354	4,446,187	0.37
46	Feathers and down, crude, not dressed, etc	2,032,566	2,476,659	2,742,018	2,036,791	2,970,260	4,401,131	4,300,721	0.37
47	Matting for floors, etc.	3,817,866	3,780,050	3,009,795	3,000,088	3,831,436	3,709,202	4,333,044	0.36
48	Art works	3,516,536	4,310,315	3,286,262	4,381,324	4,908,782	5,807,205	4,310,767	0.36
49	Cork wood, or cork bark, and manufactures of	2,464,934	2,567,580	2,295,138	2,738,319	3,313,306	4,063,982	4,249,006	0.35
50	Lead, in ore	4,497,360	4,073,099	3,374,661	3,616,476	3,534,876	3,352,534	4,147,720	0.35
51	Paper stock, crude	2,770,255	3,015,084	2,900,713	3,796,595	4,374,464	5,580,528	3,675,926	0.31
52	Spices	3,685,242	4,815,125	4,366,008	4,583,356	5,188,116	5,113,000	3,591,537	0.30
53	Hair, and manufactures of	2,055,536	2,775,084	2,727,062	3,428,404	3,854,349	3,094,599	3,561,012	0.30
54	Iron ore	2,362,544	2,351,278	1,593,279	1,670,683	2,728,854	3,360,419	2,949,462	0.25
55	Clocks and watches, and parts of	2,460,324	2,672,310	2,990,474	2,966,495	3,105,036	3,593,173	2,922,142	0.25
56	Cement	1,478,452	3,607,666	2,052,952	1,355,096	1,394,447	3,778,114	2,100,598	0.18
57	Bristles	2,047,331	2,654,604	2,367,301	2,370,498	2,695,746	3,261,877	2,097,777	0.18
58	Jewelry, and manufactures of gold and silver	2,642,345	2,007,433	2,048,821	1,303,652	1,739,953	1,779,527	1,672,275	0.14
	All other articles	50,313,903	57,875,712	52,552,007	57,131,870	73,919,068	88,063,181	74,100,712	6.21
	Total	903,320,948	1,025,719,237	991,087,371	1,117,513,071	1,226,562,446	1,434,421,425	1,194,311,792	100.00

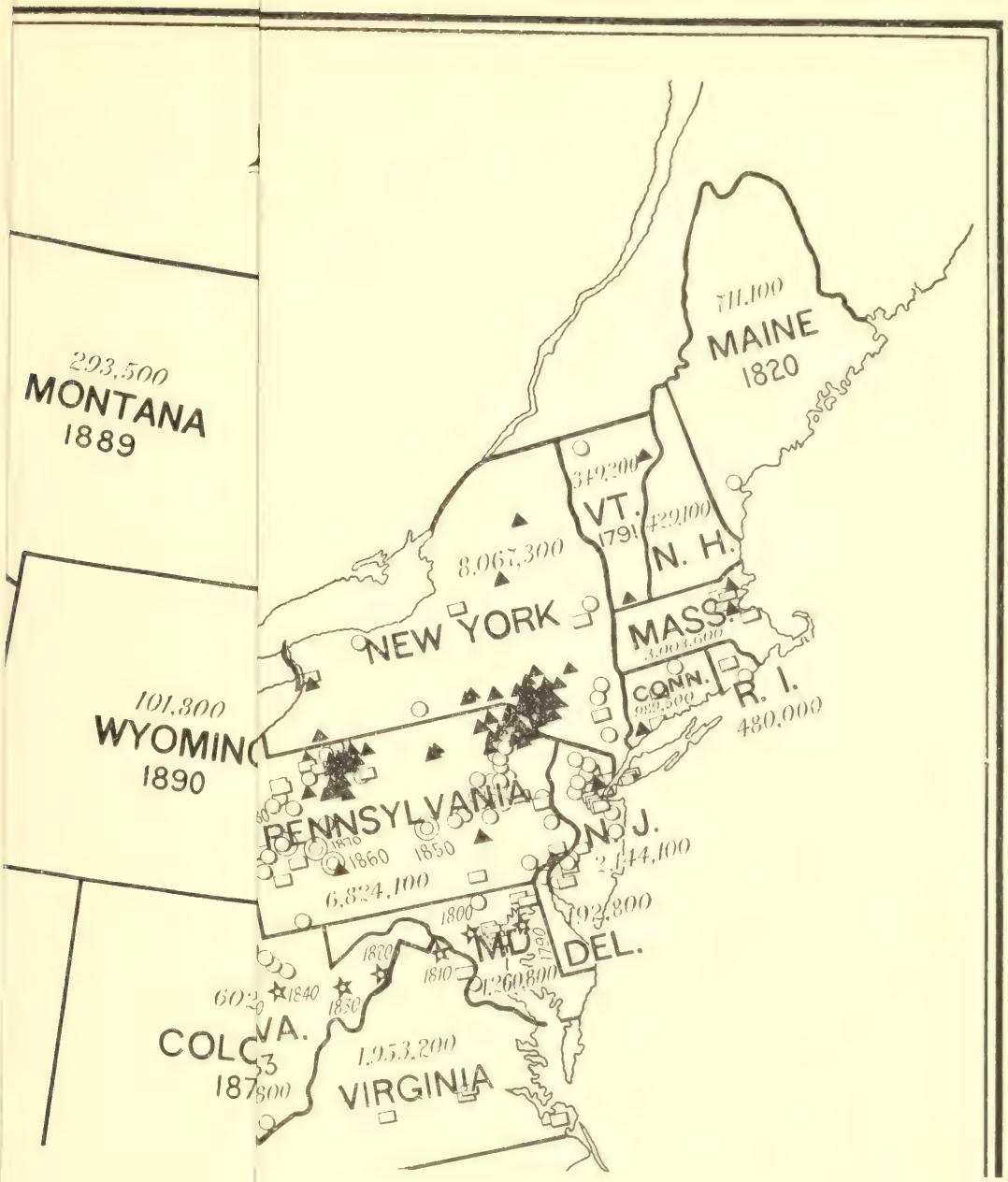
locations of each of the 1786 establishments reported for Chemicals and Allied Products at the census of 1905, and I find that seven states or territories, viz., Arkansas, Idaho, Montana, New Mexico, North Dakato, South Dakota and Utah did not at that time possess a single establishment devoted to any of the large number of industries embraced in Chemicals and Allied Products. Oklahoma, New Hampshire and Wyoming each possessed but one, and the District of Columbia, Nebraska, Nevada, Oregon, Texas and Vermont each less than five.

TABLE VI

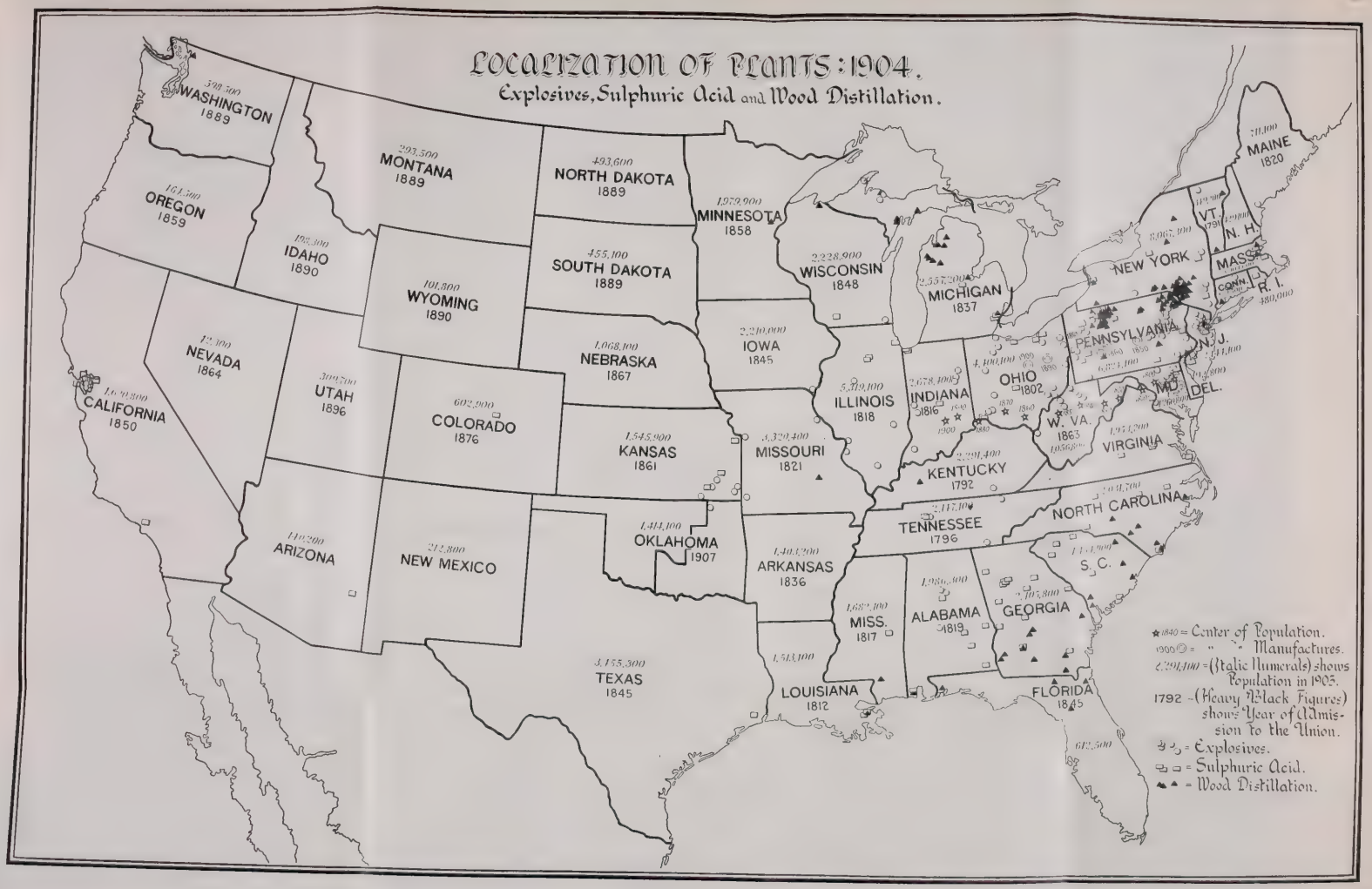
NUMBER OF ACTIVE ESTABLISHMENTS FOR CHEMICALS AND ALLIED PRODUCTS, BY STATES, 1905

	1905		1905
Alabama	27	Mississippi	7
Alaska	1	Missouri	47
Arizona	....	Nebraska	4
California	63	Nevada	3
Colorado	6	New Hampshire	1
Connecticut	40	New Jersey	144
Delaware	13	New York	264
District of Columbia	3	North Carolina	42
Florida	15	Ohio	128
Georgia	75	Oregon	4
Illinois	89	Pennsylvania	315
Indiana	52	Rhode Island	17
Indian Territory	1	South Carolina	26
Iowa	6	Tennessee	22
Kansas	10	Texas	3
Kentucky	21	Vermont	3
Louisiana	12	Virginia	62
Maine	9	Washington	9
Maryland	58	West Virginia	25
Massachusetts	77	Wisconsin	19
Michigan	52	Wyoming	1
Minnesota	10		

In order to bring this matter of the distribution of the industries manufacturing Chemical and Allied Products more clearly to your attention I have, through the courtesy of the Director of the Bureau of the Census, had prepared a map of the United States showing the location of the establishments, both principal and



293,500
MONTANA
1889
101,800
WYOMING
1890
711,100
MAINE
1820
349,200
VT.
1791
429,100
N. H.
8,067,300
NEW YORK
MASS.
3,003,600
CONN.
989,500
R. I.
480,000
PENNSYLVANIA
1870
1860
1850
6,824,100
N. J.
2,144,100
192,800
MD.
DEL.
1800
1820
1810
1790
1,260,800
1840
1830
VA.
1,953,200
VIRGINIA


LOCALIZATION OF PLANTS: 1904.
Explosives, Sulphuric Acid and Wood Distillation.
WASHINGTON 1889
OREGON 1859
CALIFORNIA 1850
NEVADA 1864
IDAHO 1890
MONTANA 1889
WYOMING 1890
UTAH 1896
ARIZONA
COLORADO 1876
NEW MEXICO
NORTH DAKOTA 1889
SOUTH DAKOTA 1889
NEBRASKA 1867
KANSAS 1861
OKLAHOMA 1907
TEXAS 1845
MINNESOTA 1858
IOWA 1845
MISSOURI 1821
ARKANSAS 1836
LOUISIANA 1812
WISCONSIN 1848
ILLINOIS 1818
MICHIGAN 1837
INDIANA 1816
OHIO 1802
KENTUCKY 1792
TENNESSEE 1796
MISS. 1817
ALABAMA 1819
GEORGIA
FLORIDA 1845
S. C.
NORTH CAROLINA
VIRGINIA
W. VA. 1863
PENNSYLVANIA
NEW YORK
MAINE 1820
VT. 1791
N. H.
MASS.
CONN.
R. I.
N. J.
MD.
DEL.
★1840 = Center of Population.
1900 ◎ = " " Manufactures.
2,291,400 = (Italic Numerals) shows Population in 1903.
1792 = (Heavy Black Figures) shows Year of Admission to the Union.
= Explosives.
= Sulphuric Acid.
= Wood Distillation.

subsidiary, manufacturing sulphuric acid, those making explosives, and those engaged in wood distillation, each being a typical industry, and the sulphuric acid industry being generally accepted as of fundamental importance.

From this chart it appears that 13 states and territories, being the 7 already named (Arkansas, Idaho, Montana, New Mexico, North Dakota, South Dakota, Utah) with Iowa, Nebraska, New Hampshire, Nevada, Oregon, and Wyoming, containing 7,648,000 out of the 76,303,387 inhabitants of the Continental United States in 1905, or over 10 per cent of the whole, did not possess a single establishment devoted to any one of these industries.

Considering sulphuric acid only, which is so important an industry that it has frequently been referred to as an index of the state of civilization of a people, we find that 23 states and territories, namely the 13 just enumerated, together with Delaware, District of Columbia, Kentucky, Maine, Minnesota, Missouri, Oklahoma, Washington and West Virginia, containing 19,562,200 population, or 25.6 per cent of the total, did not possess a single sulphuric acid plant within their borders.

Turning now to the East, we find that 11 out of the 13 original colonies, viz., Connecticut, Georgia, Maryland, Massachusetts, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina and Virginia, contained 30,695,000 population, or 40.2 per cent of the total, and 100 sulphuric acid factories, or 67.1 per cent of the total number existing in the country. Analysis of the statistics of the separate states shows that the number of these establishments does not follow the population, Georgia, for instance, with about one-fourth the population of New York, having twice the number of sulphuric acid factories that New York had.

I am aware that the number of establishments in an industry, is an unsafe criterion as to the magnitude or importance of that industry, but this feature has been chosen as lending itself most easily to graphic demonstration. I have therefore assembled, by geographic divisions, in Table VII, data for the quantity of sulphuric acid produced, and we find that inspection of this leads to much the same result as to that which was drawn from the consideration of the distribution of the establishments.

All investigations show that there is an enormous extent of fairly well-populated area in this country yet awaiting develop-

ment by the chemical engineer, and I commend this field of service to your attention.

TABLE VII

QUANTITY OF SULPHURIC ACID PRODUCED IN THE UNITED STATES BY GEOGRAPHIC DIVISIONS: 1905 AND 1900

Division.	1905.	1900.
	Tons.	*Tons*
United States	1,869,437	1,548,123
North Atlantic	768,647	734,669
South Atlantic	540,593	520,575
North Central	349,906	153,979
South Central	141,107	87,665
Western	69,184	51,235

As a field in which costs may be diminished, attention may be called to the saving of waste. So much has been said on this subject that I hesitate to dwell upon it lest I weary you. But I venture to suggest that one remedy for waste, which has not been so markedly dwelt upon as it deserves, is by a change in location, and I take as an example of this the gas industry.

I have long looked upon our present custom of transporting coal long distances to be converted into gas as uneconomic, for a not inconsiderable quantity of coal is burned to provide the energy with which to haul this coal. Not only that but, since the gas constitutes but a very small percentage by weight of the coal, there is a considerable waste in hauling the coke, with its ash, and the by-products. Further, to provide for emergencies, large stocks of coal must be accumulated in advance at the gas works, and as coal, particularly gas coal, begins to deteriorate as soon as it is removed from the mine, there is a very considerable loss going on all the time from this cause. Further, as the by-products or residuals are now purchased in the crude state in relatively small quantities at the different gas works, a large part of their value is consumed in collecting and transporting them to central refineries.

By producing the gas at the mine and shipping it by pipe line the cost of haulage in the coke, with its ash, and crude by-products is saved. The wastage of coal by weathering is saved. The cost of collection and transportation of the crude residuals is saved.

Such coke as is not needed for industrial purposes can be converted in producers into gas which, by means of internal-combustion engines, can be used in generating electricity for distribution, and the ash from this coal can be put into the mine for use as a filler in place of coal.

It is evident that gas can, under these circumstances, be made and delivered at a much less cost than is the case at present, though it may be necessary after long travel to enrich it near the point of consumption. Furthermore the valuable areas now occupied by gas plants in our cities can be given up to more concentrated industries and cheap country lands be substituted for them.

I venture further to suggest that frequently an urgent reason for saving waste is to suppress a nuisance, for I do not hesitate to assert that the existence of a public nuisance is evidence of the existence of an economic waste.

Almost at the outset of my professional life, in 1872, I became involved in the famous Miller's River Nuisance case and it fell to my lot, to examine, on behalf of the citizens of Cambridge, Mass., the large slaughtering houses which were believed to be the cause of the nuisance, and to study the operations going on within them. The conditions were very complex and there were a variety of causes which led to the creation and maintenance of this most horrible and most extensive nuisance, but among other causes I found that the slaughtering houses had permitted much valuable blood and offal to escape into the stream and that, at that time, one establishment alone was pouring into the river, in the water in which it had steamed its hogs, over five tons of gelatinous matter per week, and this was done in ignorance of the existence of this matter in tank waters.

What I have found to be true regarding matter, I have also found to be true as regards energy, and I cite as an example, the nuisance of "cannonading" in blasting, which is proof in itself of the use of unnecessarily excessive charges of explosives.

But in urging the abating of a nuisance or advising the saving of waste or the conserving of resources, we should not fail to point out that it can usually be accomplished only with added expense, and that a profit can rarely be realized unless the operations are carried out on a quite considerable scale. In fact, it seems to be an economic law that only the rich can really save; that "to him that hath shall be given"; for the poor must pay the price of much

subdivision and the consequent cost of much handling and a multiplicity of containers.

In fact, we should make it plain that the advocacy of the saving of waste in manufacture and of conserving our resources necessarily implies the use of great aggregations of capital and the carrying on of large scale operations under a single management. It means the application of methods such as have been applied with great success in the manufacture of hog products, or in the refining of petroleum. In dealing with coke at the census of 1905, I found that of the 37,376,251 tons of coal coked in the United States in that census year, only 3,317,585 tons, or 8.9 per cent, were coked in by-product ovens, and I estimated from the yields and values of the by-products which were recovered that had all the coal been coked in by-product ovens there was a possible saving of $37,492,-136.* This is an enormous amount to save in a single industry in a single year, and if the saving could be made an accomplished fact it would go far toward wiping out that humiliating account against us in our imports of "Chemicals, drugs and dyes." But I have never failed to recognize the fact that this could only be accomplished by those controlling large capital, and that it meant the "killing off" of a large number of minor establishments, and I have further recognized the fact that the apparent savings set forth could not be realized until the charges against the more costly plant had been satisfied, nor until the market had been so readjusted that it could absorb this greatly increased output of by-products.

As an example of the commercial advantage resulting from the abating of a nuisance, I cite the instance of Ducktown, Tenn., whose smelters have for decades been notorious offenders. I will not repeat to you the details by which their devastating sulphurous fumes have been converted into valuable merchandise, since they have been so well set forth in current literature, but will simply note, that, by report, this saving has resulted in the suspension of a number of the sulphuric acid works in the contiguous region, and I am ready to believe this report to be true, for I look upon this result as a natural consequence of the operation of a wholesome law in economics.

However, all of the endeavors avail but little so long as we remain a dependent nation, which the quantity of manufactured "Chem-

* Bull. 65, U. S. Census of Manufactures, 1905, p. 18.

icals, drugs and dyes" imported by us indicates that we are, and especially while we import over $7,000,000 worth of coal-tar products and nearly $2,000,000 worth of ammonium sulphate, as we did in 1908, and yet allow $37,000,000 worth of the by-products produced in the coking of our coal to be wasted. It is evident that there is still a wide opportunity for the employment of the chemical engineer in developing our chemical industries.

I find that I have been led to devote my attention to the chemical industries of the United States when you have asked me to treat of those of America. I have, however, limited myself not because I consider our country America, but because of the limited amount of information that I have been able to secure relative to the other countries in North and South America. Such as is available for Canada is found in a paper by Dr. W. R. Lang, published in the Transactions of the Canadian Institute for 1904, from which it appears that, in 1903, salt was produced in the Dominion to the value of $334,000, and arsenic, in 1901, to the extent of 1,347,000 pounds. Sulphuric acid was produced in Quebec, Ontario, and British Columbia, but neither the number of factories, nor the extent of the output is given. However, in treating of the plant at Ontario, which produced about fifteen tons of acid per day, it is stated that imported brimstone was used as the raw material and this in the face of the fact that Canada abounds in pyrites. The wood-distillation industry flourishes in that country, the plant of the Lake Superior Power Company being, it is said, the largest retort plant in the world, but no statistics of production are supplied. Ammonia liquor was produced to the extent of 235,000 pounds of 28° Bé. strength, the larger part of it being exported. Soap was produced by some fifteen concerns employing about 2000 hands, the value of the product in 1902 being approximately $3,000,000. Glycerine was obtained from the soap lyes, one works being capable of treating 10,000,000 pounds of lye annually. Petroleum refining was carried on at Sarnia, the factory being able to treat 60,000 barrels of crude oil per month. Calcium carbide was made in two works, carborundum and graphite in one. There was a limited manufacture of fine and heavy chemicals. This about completes the tale for Canada.

My efforts to obtain information relative to the Central American and South American states have been less successful, though I have searched the literature and consulted officials from and to

these countries. "The Statistical Abstract of Foreign Countries" recently published by Mr. O. P. Austin, Chief of the U. S. Bureau of Statistics, covers the exports and imports of these countries for a decade, and it appears to be the only authoritative and detailed report concerning them, yet a painstaking search of the tables of exports for each of these Central American and South American countries shows no other chemical items than borate of lime, iodine, and nitrate of soda from Chili; charcoal from British Guiana and Argentina; fermented and distilled liquors from several of the countries, especially from the West Indian Islands; and dyestuffs and extracts from a number of states. Literature relating to the commercial resources and industrial activities of the Pan-American republics, other than the United States, is apparently quite meager, and information regarding their industrial activities appears not to have been collected either by the countries themselves or by students of commerce and industry. It does appear, however, from what information can be obtained, that the resources of these countries are in an undeveloped condition and that these countries present an almost virgin field for development by the chemical engineer.

I have myself attempted to inspire one such development, for at the outset of the undertaking of the construction of the Panama Canal by the United States, I advised that dynamite, which has been consumed in enormous quantities in the excavation work, and the manufactured "raw" materials of its manufacture, be made upon the Isthmus. The easy access to the nitrate of soda deposits of Chili, making but a brief water transportation necessary for delivery, and the existence of pyrites in great abundance in the vicinity of the Isthmus, making the production of sulphuric, and hence mixed, acids easy and simple were a few of the many advantages which would follow the adoption of this plan. But not the least would be the civilizing influence which chemical manufacture always exerts. It is unnecessary to say that up to the present, I have been unsuccessful in my endeavors to introduce chemical manufactures into the Central American states, but I trust that you, who have done me the honor to listen to me, may succeed where I have failed.

CONSERVATION AND THE CHEMICAL ENGINEER

Address by President SADTLER

Delivered at the Philadelphia Meeting, Dec. 9, 1909

We have heard much in the last year or two concerning the conservation of our natural resources, and we shall, I feel certain, hear much more in the next few years, as the facts elicited from the preliminary studies of the subject come to be understood by the public at large. The importance of the subject will grow correspondingly as the matter is studied by the thoughtful citizen, and his appreciation of it will in time be reflected in the activity of the statesmen at Washington in the proposing of remedial measures.

Conservation, let us note, however, represents the third stage in the history of the development of natural resources.

The first stage is exploration or discovery. This is the era of the prospector and has given us in this country some famous episodes. We need only recall the discovery of gold in California in 1849 and the way in which it operated to attract adventurous spirits from the older parts of our country, or the repetition of the same story with the discovery of the rich gold deposits on the Yukon and at Nome in Alaska.

The first discovery of the rich petroleum deposits of western Pennsylvania in the early sixties brought, similarly, multitudes of prospectors or "wild-catters," as they came to be known locally, and this experience has been repeated also from time to time as great petroleum gushers or powerful gas wells have been reported in various sections of the country, resulting in the opening of new fields, as in Ohio, Indiana, Kansas, Texas, and Oklahoma.

The second stage is exploitation, when these lavish gifts of nature are worked with a view mainly of increasing production, and usually in a wasteful way, with no thought of the exhaustion of the supply.

As illustrations of this stage we need only cite the way in which

our coal mines have been worked. In Bulletin 394 of the U. S. Geological Survey (Papers on the Conservation of Mineral Resources), we find the statement that "It has been estimated that the actual loss or waste sustained through coal left in the mines in conducting mining operations amounts to 50 per cent of the quantity produced and marketed." Worse than this, when the Anthracite Coal Waste Commission made its report in 1893 they estimated that "For every ton produced 1½ tons were lost."

One of the most valuable gifts of nature is the natural gas which is associated more or less directly with petroleum. It is a fuel of the greatest value, being nearly pure hydrocarbon in its composition. Yet we find in the same Bulletin of the Geological Survey before referred to the following: "As to the amount of natural gas which is being wasted daily, no accurate statistics have been attempted, and the judgment of Dr. I. C. White, State Geologist of West Virginia, may well be accepted to the effect that no less than 1,000,000,000 cubic feet of gas are wasted in the production of oil." This waste Dr. Day of the Geological Survey says "Practically equals the annual consumption of natural gas reported for 1907. This waste should furnish light for half the urban population of the United States."

The exploitation of our once great timber resources and the resulting denudation of great tracts of land and the evils to the soil which have followed in the train of this ruthless waste have been so graphically portrayed by the U. S. Forestry Bureau and others recently that I need not more than allude to this case of reckless extravagance.

It is not my intention, however, to take up this evening the question of the conservation of our natural resources and the absolute need thereof, as so ably developed in recent reports of the 'National Conservation Commission," the Forestry Bureau and other official publications, nor yet the part played by the chemist in this Conservation of Natural Resources which has been so ably reviewed by Dr. Bogert in his recent Presidential address before the American Chemical Society.

What I would like to do is to indicate that these same three stages of exploration or discovery, exploitation or effort at production, and finally conservation are to be seen in the history of every great chemical industry, and to point out that, while it is the part of the chemical engineer to aid in the exploitation step,

what is still more important is his part in counseling and indicating how the wholesome influence of conservation can be applied so as to broaden and extend the scope of the industry, to maintain and add to its remunerative character and to give it stability and promise of permanence.

Let us illustrate this view by examples and take first the great petroleum industry to which reference has already been made in speaking of the era of exploration, when the petroleum fields were first outlined by the work of the prospector and driller.

The second stage of exploitation began to draw upon the help of those who were chemical engineers, in fact if not by title. The development of the distilling and refining processes came first. Starting with the old cheese-box still with its circle of heating grates under it, there was a change, following upon the discovery of the "cracking process" as applied to crude oil, to the present form of cylindrical still with its movable cover to regulate the chilling of the vapors during the latter part of the operation. This simple feature in distilling enables the refiners to get 75 per cent or higher of burning oil from the crude petroleum instead of the 45 per cent of a normal fractional distillation, while producing a residuum which can be advantageously distilled for paraffin oils.

The proper control of the acid and alkali treatment of the crude distillates, the change from the old forms of presses for paraffin scale to the modern filter-press, the introduction of bone-black filtration for reduced oils and residuums, all contributed to develop and expand enormously the several parts of the industry to which they were applied. With these improvements in large-scale methods went the inauguration of improved testing and analytical methods so that the uniformity of product so essential for sound business development was secured.

Let us turn now to the newer evidence of the work of the chemical engineer in the way of conservation as illustrated in this same industry. The collection and utilization for fuel purposes of the uncondensed gas from the distillation of crude oil is one of the important economies that have been generally adopted. The working up of the sludge acid and recovery of not only sulphuric acid, but of valuable side-products, is now a feature of the larger refineries. The introduction of clay filtration to improve the quality of the heavier grades of oils is an important advance as well as a step of economy. The production of gas oils from the

less valuable crude oils has also become an important industry, as these are of great value for gas making and gas enriching. The more thorough utilization of residues is also a feature of recent years. From these residues are now made excellent road oils for the aid of the good roads movement. The petroleum pitch is all utilized also, partly for electric-light carbons and partly for fuel purposes. Most promising of all, however, is the result, not as yet fully attained, but most certain of solution in the immediate future, viz., the utilization of crude petroleum of the lesser valuable kinds and residuums in internal combustion engines for the development of power.

A second typical industry is that of coal distillation. We have already spoken of the wastage in the mining of coal. It is not necessary here to speak of the corresponding waste in its utilization as fuel. We will speak solely of the distillation of coal. This treatment may be carried out from either one or two points of view, and the exploitation in each case has been pushed with great energy, utilizing all available chemical and engineering skill. The first is the distillation for the manufacture of illuminating gas. While the mechanical side of this process has advanced steadily, particularly after the introduction of regenerative firing and mechanical stoking, the chemical side did not advance so rapidly. While the coal tar is no longer thrown away, unless it be in very isolated localities, the proper chemical utilization of this tar has lagged behind both in this country and England. On the other hand, the true conservation of this valuable side-product and the development of its possibilities has advanced in a notable degree in Germany, the home of the coal-tar industry. Here the research chemist and the chemical engineer have gone hand in hand in the building up of a great industry, or rather two industries, based upon the utilization of the coal tar, the manufacture of the coal-tar dye colors and the manufacture of synthetic medical preparations possessing valuable therapeutic characters. Besides these most important and highly developed illustrations of conservation, we have, however, some minor utilizations of coal tar or products from the same that deserve mention. Thus the manufacture of creosote oils for the preservative treatment of wood, the roofing pitch and tar-paper manufacture and the use of pitch in the briquetting of coal are illustrations of value given to the coal tar and its products.

The thorough extraction of the ammonia and the impurities like the cyanides from the ammoniacal liquor and the production of commercially valuable products from them is, moreover, an accomplishment in the way of conservation. The utilization too of the gas carbon for the manufacture of electrode carbons, battery plates and for electric-light carbons is another illustration of this work.

The second method of distilling coal is that for the production of coke for metallurgical purposes. This has been developed or more properly exploited to such a degree that, according to the "Mineral Resources of the United States" published by the U. S. Geological Survey, the production of coke for the year 1907 was 40,779,564 tons, of which, however, 35,171,665 tons were produced in beehive ovens. In these, as is well known, only the fixed carbon of the bituminous coal is saved, and all volatile constituents, including gas, tar and ammonia, are absolutely wasted. On the other hand, 5,607,899 tons of coke were produced in by-product recovery ovens and the value of the by-products (gas, tar and ammonia) obtained therefrom amounted to $7,548,071. It is easy to reckon from this what the loss was on the 35,171,665 tons of coke made in beehive ovens. In fact, the article on "coal," in Bulletin 394 before referred to, says with reference to this, "At the prices which prevailed in 1907, the value of the by-products wasted in beehive coke ovens was a little over $55,000,000."

But the result achieved by the chemical engineer in the working of this by-product oven represents more than merely saving certain by-products. As we will see on our visit to-morrow to the by-product ovens at Kaighn's Point, Camden, the gas produced can be separated by the perfect control of the method into "poor gas" for fuel purposes and "rich gas" for illuminating purposes, so that the highest economy or conservation of values is thereby attained.

Another industry in which the chemical engineer has worked first for the purpose of exploitation and later for conservation of material and values is the starch industry. Starch, as we all know, is one of the most widely distributed vegetable products and has always played a great part in the world's supply of food. In Europe, it is potato and wheat starch, in the United States it is corn starch, and in tropical countries it is rice, tapioca, sago, etc., that are the important varieties of this cereal food. Not only has

the production of starch been developed, however, for food purposes, but enormous quantities of the starchy substances serve as the starting point in the fermentation industries. Then we have the use of both starch and its alteration product, dextrine, in the textile industries, and the production of glucose as the product of the hydrolysis of starch, and the manufacture of nitro-starch and its utilization in the explosives industry. All of these industries have attained a high degree of perfection by the application to them of a chemical understanding of the nature of starch and its alteration products and the devising of processes by which the several reaction changes could be carried out with exactness and economy. What that means as applied to one single branch of the starch industry, those of us who had the opportunity on the occasion of our meeting last June to go through the works of the Corn Products Refining Co., at Edgewater, N. J., can appreciate. The glucose production of the United States in 1907 is stated to have been 800,000 tons, requiring 40,000,000 bushels of corn as raw material. But besides the production of the solid grape sugar and the liquid glucose for a great variety of uses, the separation of the germ of the corn from the starchy portion has made possible the production on a large scale of corn-oil, a product adapted for a wide range of uses, from soap-making to the manufacture of rubber substitute.

Turning now to inorganic chemistry for an illustration, we have a splendid example of the work of the chemical engineer in the direction of conservation in the case of the natural and artificial nitrate industry, to which latter the Germans have already given the expressive name of "air-saltpetre." The great source of nitrate for forty or more years past has been the deposits on the west coast of South America, furnishing the so-called Chili saltpetre or sodium nitrate. This has been drawn upon increasingly until in 1908 the quantity shipped was 1,730,000 tons, valued at $87,500,000. But the Chilian deposits are far from being inexhaustible. It is estimated that if the annual consumption increases merely by 50,000 tons, and this is to be reasonably expected, from 30 to 40 years will see the practical exhaustion of this supply. So in 1899 Sir Wm. Crookes startled the industrial world by calling attention, in what the newspaper men would call a "scare article," to the nitrogen problem and the necessity of maintaining a supply of nitrogenous plant food if the world's food requirements were to

be met. Crookes pointed out the way of relief when he said, "the fixation of atmospheric nitrogen is one of the greatest discoveries awaiting the ingenuity of chemists. It is certainly deeply important in its practical bearings on the future welfare and happiness of the civilized races of mankind." The chemical engineer has responded nobly to this demand for conservation of available nitrogenous material by the working out of practical methods for the manufacture of what we called "air-saltpetre." It must not be supposed, however, that success was easily obtained. Not only were there the usual experimental difficulties to be overcome but, as Prof. Berthsen has well shown in his address before the London International Congress of Applied Chemistry in May last, there are theoretical difficulties of the most serious kind standing in the road of ready fixation of atmospheric nitrogen and oxygen in the form of nitrogen oxides convertible into nitrates. So it happened that the first large enterprise of this kind, the process of the Atmospheric Products Company, established at Niagara Falls, had to be given up as commercially unavailable. This was followed by the Birkeland and Eyde process, started in Norway with the cheapest water power to be found, and this is still in successful operation. A few years later (in 1905), the Schönherr process was worked out by the Badische Anilin und Soda Fabrik, also using Norwegian water-power, and still later the Pauling process at Gelsenkirchen near Innsbruck in the Tyrol. Of these the Schönherr process seems to be the most successful and economical. It produces a 40 per cent nitric acid, calcium nitrate, or calcium or sodium nitrite, according as the absorption part of the process is modified. All of the processes mentioned require the cheapest electrical energy, which can only be developed by cheap water-power and thus far best developed in Norway. Prof. Berthsen states, however, that probably within a few years the annual output of calcium nitrate or "air-saltpetre" will reach 100,000 tons. As this involves first the fixation of atmospheric nitrogen, and second the use of "white coal," as water-power is sometimes fancifully called, it is a true lesson in conservation of natural resources, especially as it also enables us to replace a rapidly disappearing natural product.

Closely related to this recently developed inorganic industry of air-saltpetre is the slightly older one of calcium carbide and its offshoot, the cyanamide or "nitrolime" industry. With the production of calcium carbide in the electric furnace in 1892 by Willson,

and the publication of Moissan's work on the electric furnace in 1894, sprang into existence a great industry, as the acetylene gas lighting made possible thereby had great advantages. Isolated lighting plants, acetylene lamps for automobiles and carriages, luminous buoys and signals, a new material for lamp-black manufacture, and other utilizations all were rapidly developed. The perfecting of the furnaces and the process for the manufacture of carbide enlisted the attention of electrical and chemical engineers, and at the present time the world's production of calcium carbide is estimated to be about 20,000 metric tons per annum, largely in countries like Norway, Italy and Switzerland, where cheap water-power is available, as well as in the United States at Sault Ste. Marie and elsewhere with similar conditions. This production, however, for the time being outran the demand for carbide for acetylene lighting.

Relief from overproduction by finding new outlets and utilizations is always to be preferred to closing of works already in operation, so chemical engineers have found new possibilities for calcium carbide. By far the most important of these is the production from calcium carbide of calcium cyanamide by the action of nitrogen gas, as worked out by Drs. Frank and Caro. We have here an exothermic reaction in which nitrogen is absorbed by the carbide with the production of calcium cyanamide and carbon. This takes place at a temperature of from 800° to 1000° C., much below that needed for the carbide manufacture. Not only can all the nitrogen of this cyanamide be converted into ammonia by decomposition with steam, but it is gradually decomposed by the chemical and bacteriological constituents of the soil into ammonia, which becomes fixed by the vegetable mold and is so held. The cyanam de is also convertible into calcium cyanide by melting with fluxes, into dicyandiamide for dye-color manufacture, into urea, guanidine and other hitherto relatively expensive organic compounds. The dicyandiamide is already used as a deterrent in smokeless powder manufacture, reducing the temperature of the explosion without diminishing explosive force, and the crude calcium cyanamide with certain fluxes, under the name of "ferrodur," is employed for case-hardening of iron and steel.

The statement is made that the works for the manufacture of "nitrolime" now in operation, or in course of construction, have a capacity of 166,000 tons per year.

The illustrations of conservation, whether from the point of view of better utilization of materials, of the production of new and varied products or the recovery of what were waste products could be greatly extended did time allow.

We might refer to the way in which sulphur recovery has been worked out in the alkali industry, or to the manganese recovery in connection with the chlorine production from manganese dioxide, so that "recovered manganese" is to-day a most valuable article of commerce. Or we might note the saving resulting from the manufacture of reclaimed rubber, a subject which we will have an opportunity of hearing about on Friday from one who has had large experience in this line, and seeing the practical side of it in our excursion the same day, but these and similar illustrations of the conservation theme as influenced by the work of the chemical engineer will have to be passed by for the present.

That there are numerous problems as yet unsolved, of equal and possibly greater importance than some of these discussed, will also be conceded by those possessing even a moderate acquaintance with chemical industries.

One of these problems for instance is the recovery of the valuable constituents of the waste-liquor of the sulphite wood-pulp process. A German authority states that every liter of this waste liquor contains 120 grams of organic material as against 10 to 15 grams of mineral substance. Dr. A. Frank estimated that in 1904 there was wasted in this way in Germany 300 million kilograms of organic material, concerning which we know it has value in several directions. In this country, the sulphite wood-pulp process has also an extensive development and the same waste liquor is run off into our streams.

A somewhat different problem, but one of even greater importance, is the loss of valuable metals in smelter smoke and fumes. The American production of bismuth is not over 10,000 pounds a year, and considerable amounts of bismuth and bismuth compounds are imported every year. Yet it is estimated in the forthcoming report of the U. S. Geological Survey for 1908 that 880 pounds of bismuth per day are being thrown off in the smoke of the great Washoe smelter at Anaconda, Montana, and with this also goes copper, lead, zinc, arsenic and other mineral products. One way of saving much of this lost material is pointed out in noting that the replacing of smelting methods by electrolytic

methods, possible in some cases, allows these metals to be recovered from the deposited slimes.

In conclusion, let us emphasize the fact that our chemical industries need not merely development or exploitation, but if they are to continue to flourish as we are drawn more and more into international competition, they must have the newest and best results of chemical research applied by the experienced chemical engineer. New and better materials must be sought, better processes evolved, economies effected at all possible stages and waste products carefully looked after. The most successful chemical industries in the world, which show the highest scientific and technical development, and which are steadily expanding and throwing out branches, are those of the great German chemical companies. Organizations like the Badische Anilin und Soda Fabrik, which have by their employment of both research chemists and chemical engineers effected industrial revolutions, one after the other, like the introduction of artificial indigo, the contact sulphuric acid manufacture, and, last of all, the production of air-saltpetre or artificial nitric acid and nitrates, are those which reap the rich commercial rewards, and for the reason that they have done the work and earned them. The hope of a successful American chemical industry lies in the same direction.

EFFICIENCY LIMITS IN THE POWER-GAS PRODUCER

By WILLIAM D. ENNIS, Professor of Mechanical Engineering in the Polytechnic Institute of Brooklyn

Read at the Brooklyn Meeting, June 24, 1909

Theory of Producer Operation. The aim of the operation of a steam boiler is to evolve all of the heat from the fuel while in the furnace. This heat is utilized for steam making at the point of generation. Any heat carried away in the products of combustion discharged from the boiler is lost. In a power-gas producer, the heat is employed at some distance from the producer itself. In a coke-oven or coal-gas retort, the heat to be utilized is that of hydrocarbon gases distilled from the coal by externally applied heat. No combustion should occur in the retort. The heat supplied to distill the gases is carried away by them as sensible heat or heat of temperature. The residual coke contains, usually, the larger part of the heating value of the original coal. The retort distillation of coal is thus primarily a coke-making process and only incidentally a gas-making process.

In the usual type of power-gas producer, no coke is made: but the fixed carbon, as well as the hydrocarbons, is converted into gas. It unites chemically with oxygen from the air, forming carbon monoxide. Heat is evolved, amounting to 4450 B.T.U. per pound of carbon. This heat itself serves to produce gasification. No externally applied heat is needed. The heat evolved by the combination is, however, obtained at heavy expense, and if its evolution were not inseparable from the change of carbon to carbon monoxide, externally applied heat might be more economical.

The evolution of heat in the producer causes an elevation in the temperature of its products. Let the fuel be assumed to be pure carbon. The amount of oxygen necessarily supplied per pound of carbon is 1.3333 pounds. If this oxygen is supplied from the atmosphere, there will enter the producer with it $1.3333 \times 77/23$

$=4.463$ pounds of nitrogen. The gas discharged from the producer will then consist of this amount of nitrogen, with 2.3333 pounds of carbon monoxide, a total of 6.7963 pounds per pound of carbon gasified. Taking the specific heat of nitrogen at 0.245, and that of carbon monoxide at 0.247, the gases from a pound of carbon, in rising one degree in temperature, will absorb heat amounting to

$$2.3333 \times 0.247 = 0.57633$$
$$4.463 \times 0.245 = 1.09344 \qquad 1.66977 \text{ B.T.U.}$$

Since 4450 B.T.U. are available to cause a rise of temperature, the temperature elevation will be $4450 \div 1.66977 = 2665°$ F. The original fuel contained 14,500 B.T.U. per pound. Of this, 4450 B.T.U. have been evolved. There remain in the gas, as heat of combustion, only 10,050 B.T.U. The heating value of a pound of the gas is $10{,}050 \div 6.7963 = 1479$ B.T.U. The proportion of carbon monoxide (the active constituent) in the gas is $2.3333 \div 6.7963 = 0.3435$.

Besides the heating or combustible value of the gas, it is further endowed with heat by reason of its high temperature. If the gas is to be used in a metallurgical furnace, the heat due to its temperature is useful and may in some cases be utilized. In such cases, the efficiency will be close to 100 per cent. The apparatus is then analogous to that of a furnace fired directly with coal, in which the evolution of gas from the coal and the burning of that gas occur in a single chamber. If, however, the gas is to be used in an engine, its high temperature is of no advantage and imposes serious mechanical disadvantages; so serious that cooling must be provided for. The heat used in producing elevation of temperature is wholly lost. Since this heat, per pound of carbon, is 4450 B.T.U., while the total heat in carbon is 14,500 B.T.U., the efficiency of the producer, on a cold-gas basis, cannot exceed $(14{,}500 - 4450) \div 14{,}500 = 0.6931$. The heat wasted is then 30.69 per cent of the total heat. This formula for gas-producer efficiency may be compared with that for efficiency of a steam boiler:

$$\frac{T - t}{T - t_0}$$

in which T is the temperature attained in combustion, t_0 the initial temperature of the fuel and air, and t the temperature of the steam

in the boiler. Both formulas answer for establishing maximum limits only, and both are approximate even at those limits. It is interesting to note that under such reasonable conditions as $T=2850$, $t=325$, $t_0=60$, we have for the limit of efficiency of the steam boiler approximately 0.91, such a value as might have been expected.

Methods of Increasing Producer Efficiency. In order to increase the efficiency of the producer, we must in gas engine practice adopt some method for reducing the amount of sensible or temperature heat in the gas. We cannot reduce the heat evolving power of carbon burned to carbon monoxide, which is always 4450 B.T.U. per pound. We cannot reduce the amount of oxygen necessary for gasifying this carbon. We might attempt to derive the oxygen from some other source than the atmosphere; but this would apparently not affect the efficiency. It would merely change the quantity of gas, and the temperature attained, without reducing the loss of 4450 B.T.U. or 30.69 per cent. The preheating of the air supplied to the producer does not solve the problem. This takes heat from the gas discharged, lowering its temperature; but the 4450 B.T.U. of loss are not affected and the temperature of the discharged gas subsequently produced from the preheated air becomes higher than before. Theoretically, if the gas is to be used for metallurgical work, such preheating of the air supply to the producer is of no value. If the gas is to be used in an engine, preheating is of benefit in mechanical respects only. The use of the sensible heat in *burnt* gas for preheating the air supplied for combustion in the metallurgical furnace is of course of great value. This regenerative action leads to higher temperatures in the furnace, which is just the result aimed at. In the engine, no such gain is permissible. No possible manipulation of the gas can in this case increase the efficiency of the engine or of the producer by utilizing the wasted sensible heat.

The only vulnerable point of attack is toward the 4450 B.T.U. lost in the largely unnecessary evolution of heat in the producer. Temperatures of 2665° F. are not necessary for the formation of carbon monoxide. A heat evolution of 4450 B.T.U. is not necessary, but merely incidental. If we could reduce this heat evolution in some way, or reabsorb some of this heat after it is evolved, we should decrease the loss. To reabsorb the heat would, however, do no good unless the wasted

heat thus absorbed were transferred to the useful heat of combustion of the gas. To effect such a transfer, we may supply to the producer some compound which will absorb heat in decomposing, the absorbed heat being afterward evolved by the combustion of the elements of the decomposed substance in the engine. The substance which is commonly used is *steam*. This enters the producer and is there decomposed into hydrogen and oxygen, absorbing heat and consequently lowering the temperature. The hydrogen now carries to the engine the heat which was absorbed in the producer, not as a high temperature, but as a combustible value.

Effect of the Use of Steam. Assume, for example, that the steam supplied is to furnish 1/10 of the oxygen necessary. Of the total oxygen, then, the steam furnishes 0.1333 pounds, and the air the remainder, or 1.2 pounds. The nitrogen supplied by the air will be $1.2 \times 77/23 = 4.017$ pounds. The hydrogen supplied by the steam will be $0.13333 \times 2 \div 16 = 0.0167$ pounds. The total weight of gas will be $2.3333 + 4.017 + 0.0167 = 6.364$ pounds, of which carbon monoxide will be the $2.3333 \div 6.364 = 0.3664$ part.

To compute the evolution of heat, we remember that in decomposing steam containing one pound of hydrogen about 62,000 B.T.U. are absorbed. (The initial temperature of the steam is 350° F., its pressure atmospheric, and the final temperature of the hydrogen and oxygen may be taken at 2250° F., this figure being one to be justified later in the computation.) The heat of decomposition for the weight of hydrogen introduced is then $.0167 \times 62{,}000 = 1035.4$ B.T.U. This reduces the evolution of heat in the producer to $4450 - 1035.4 = 3414.6$ B.T.U. The heat required to raise the temperature of the gas 1°F. is

$$\begin{aligned} 2.3333 \times 0.247 &= 0.5763 \\ 4.017 \times 0.245 &= 0.9842 \\ 0.0167 \times 3.4 &= 0.0568 \qquad 1.6173 \text{ B.T.U.,} \end{aligned}$$

the specific heat of hydrogen being 3.4. The elevation of temperature is $3414.6 \div 1.6173 = 2111°$ F. The temperature *attained* will be perhaps 150° greater, a figure sufficiently close to that assumed in the computation.

The producer efficiency, on a cold gas basis, is now $(14{,}500 - 3414.6) \div 14{,}500 = 0.765$. The steam used is 0.15 pounds; the air,

5.217 pounds. The proportion of steam to air is 0.0289. The heating value of the gas is $(14,500 - 3414.6) \div 6.364 = 1741$ B.T.U. per pound. The temperature of the gas has been reduced, while the percentage of carbon monoxide, the heating value and the efficiency have been increased. The following gives the results:

TABLE I

PRODUCER OPERATION WITH AND WITHOUT STEAM

	With Steam	Without Steam
Per cent of CO, by weight	36.64	34.35
B.T.U. lost in producer	3414.6	4450.
Temperature elevation, °F	2111.	2665.
Efficiency, per cent	76.5	69.31
Percentage of steam used	2.89	0.
B.T.U. per pound of gas	1741.	1479.

By using more steam, we might have further increased the efficiency, while decreasing the producer temperature. In order to depict the results, the accompanying chart (Fig. 1) has been prepared, the solid lines showing the effects following the use of various proportions of steam to air. Table II gives the computations in detail. The temperatures assumed in computing the heat of decomposition of hydrogen check roughly against those obtained as a result of the calculation. As the supply of steam is increased, the heating value of the gas and the efficiency are both increased, as are the percentages of carbon monoxide and hydrogen in the gas. *The temperature elevation decreases.* In this lowering of attained temperature, we find the factor which limits the possible gain of efficiency following the use of steam. The elevation of temperature becomes nil when the proportion of steam is about 0.26. Practically all of the heat is then used to decompose steam. This would be ideal operation, giving an efficiency of 100 per cent if it were possible. But the decomposition of steam requires not merely the application of a definite quantity of heat; it involves, as well, a definite temperature. So also, the formation of carbon monoxide from the fuel can take place only at a considerably elevated temperature. The amount of steam that can be used is thus limited by the resulting temperature. The efficiency is limited from the same cause. Too much steam will put out the fire.

Limiting Temperatures in the Producer. Experiments are quoted* showing that the decomposition of steam is effected with

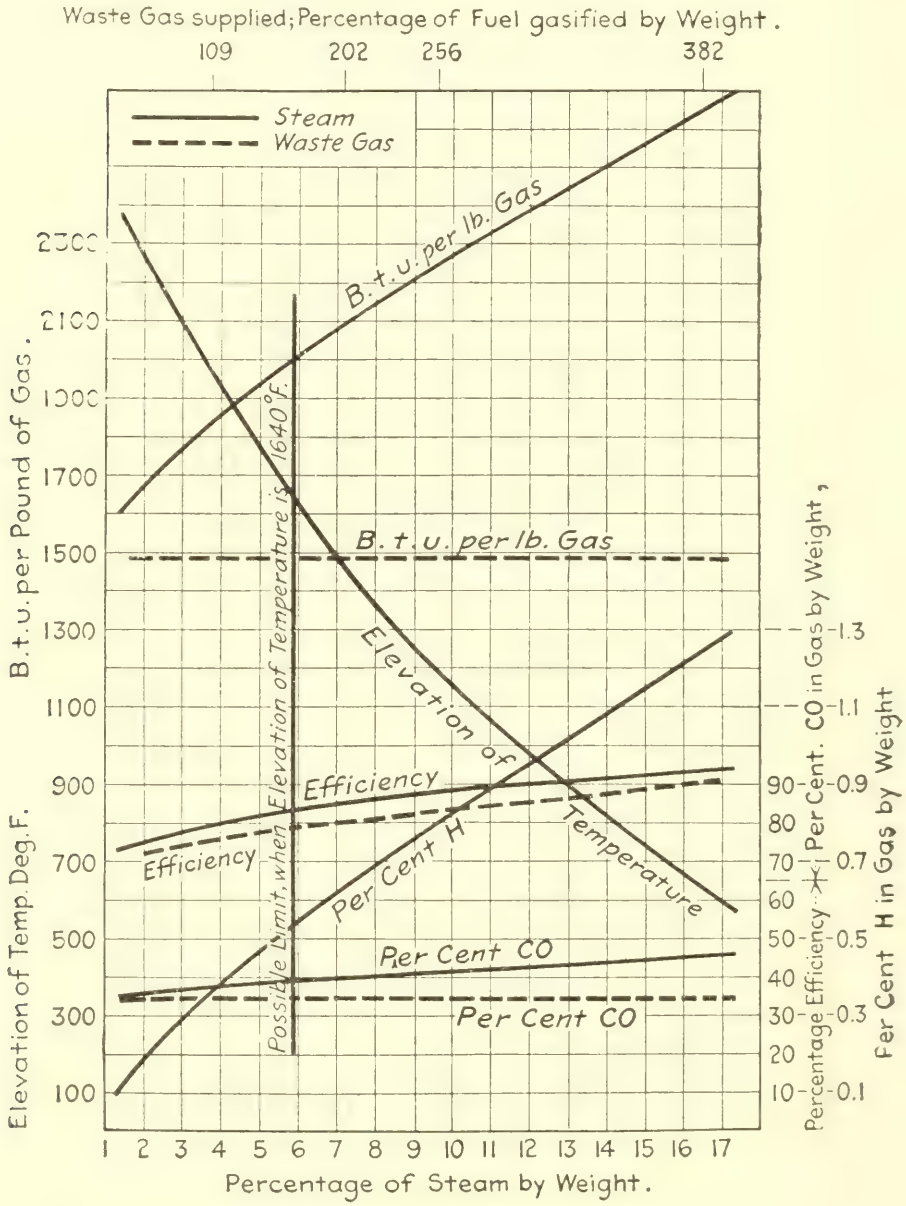


FIG. 1.

extreme slowness when the temperature is reduced to about 1740° F. The corresponding elevation of temperature may be taken at

* Those of Bunte, in Wyer's "Producer Gas and Gas Producers," 1907 ed., p. 68.

Table II

RELATION OF STEAM SUPPLY TO PRODUCER OPERATION

(One pound of pure carbon gasified by $1\frac{1}{3}$ pounds of oxygen: no excess of oxygen present)

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*
2650	64,814	5	0.0667	1.2667	4.24	0.00833	539	3911	0.576	1.038
2340	63,214	10	0.1333	1.2	4.01	0.01666	1052	3398	0.576	0.982
2010	61,454	15	0.2	1.1333	3.78	0.025	1537	2913	0.576	0.928
1710	59,974	20	0.2667	1.0667	3.56	0.0333	1995	2455	0.576	0.872
1422	58,504	25	0.3333	1.	3.35	0.04166	2440	2010	0.576	0.821
1155	57,124	30	0.4	0.9333	3.12	0.05	2860	1590	0.576	0.764
650	54,544	40	0.5333	0.8	2.68	0.0666	3630	820	0.576	0.657
185	52,163	50	0.6667	0.6667	2.22	0.08333	4350	100	0.576	0.545

L	*M*	*N*	*O*	*P*	*Q*	*R*	*S*	*T*	*U*
0.0284	1.6424	2380	72.8	1605	6.578	1.36	35.5	64.1	0.1
0.0568	1.6148	2105	76.5	1755	6.357	2.88	36.8	62.9	0.3
0.0852	1.584	1840	79.6	1882	6.135	4.59	38.1	61.5	0.4
0.1135	1.5615	1570	83.2	2040	5.926	6.5	39.4	60.0	0.6
0.142	1.539	1310	86.1	2188	5.725	8.4	40.9	58.4	0.7
0.170	1.51	1055	89.0	2353	5.5	11.1	42.5	56.6	0.9
0.227	1.46	561	94.5	2700	5.08	17.3	46.0	52.7	1.3
0.284	1.405	71	99.2	3112	4.636	26.0	50.2	48.0	1.8

A = assumed temperature in producer, ° F.;
B = corresponding heat of decomposition per pound of hydrogen, B.T.U.;
C = percentage of total oxygen supplied by steam;
D = oxygen from steam, lbs.;
E = oxygen from air, lbs.;
F = nitrogen from air, lbs.;
G = hydrogen from steam, lbs.;
H = heat absorbed by decomposition of hydrogen, B.T.U.;
I = net heat evolved, B.T.U.;
J = heat absorbed by gas per 1° F. elevation of temperature, B.T.U., by CO
K = heat absorbed by gas per 1° F. elevation of temperature, B.T.U., by N_2;
L = heat absorbed by gas per 1° F. elevation of temperature, B.T.U., by H_2;
M = heat absorbed by gas per 1° F. elevation of temperature, B.T.U., total;
N = elevation of temperature, ° F.;
O = efficiency, per cent;
P = heating value of gas, B.T.U. per lb.;
Q = weight of gas per pound of carbon, lbs.;
R = percentage of steam to air;
S = percentage composition of gas, CO;
T = percentage composition of gas, N_2;
U = percentage composition of gas, H_2.

about 1640° F., at which (from the chart) the steam amounts to about 5.86 per cent of the air supply by weight. The efficiency is then 83 per cent. This limiting percentage of steam is a usual one in producer operation. (Wyer, op. cit., p. 69.) The vertical black line in the chart represents the limiting condition. Those portions of the curves to the right of this line are imaginary, so far as practicable operation is concerned.

We may assume a temperature of about 1800° F. as necessary for the formation of carbon monoxide. This sets a limit to efficiency which occurs at about the same point as that already fixed. Nearly the same limit is given by Wyer (op. cit., p. 69), the statement being made that in the "decomposition zone" of the producer the temperature must be maintained at about 1900° F. The limiting theoretical efficiency of the producer gasifying pure carbon with air and steam is thus about 83 per cent, on a cold-gas basis, which is the only basis to be considered in power work.

Use of Waste Gas from the Engine Exhaust. A similar operation, aiming at increased efficiency, is that in which the waste gases from the engine exhaust are mixed with air for blowing the producer. These gases are mainly carbon dioxide and nitrogen. The former is decomposed into carbon monoxide and oxygen, the carbon monoxide, like the hydrogen in steam, carrying heat of combustion back to the engine at low temperature. The process may be analyzed for a fuel assumed to be pure carbon, as before. The operation starts with air only, and the first gas consists, per pound of fuel, of 2.3333 pounds of carbon monoxide and 4.463 pounds of nitrogen. At the engine, assuming just the theoretically necessary amount of air to be supplied, the monoxide is burned to 3.667 pounds of carbon dioxide, the added 1.3333 pounds of oxygen carrying in with them 4.463 pounds more of nitrogen, so that the exhaust gases consist of 3.6667 pounds of carbon dioxide and 8.926 pounds of nitrogen, in a total of 12.5927 pounds produced per pound of fuel gasified in the producer.

The heat of decomposition of carbon dioxide to carbon monoxide is 10,050 B.T.U. per pound of carbon. Assume 1.38 pounds of exhaust gas to be returned to the producer per pound of fuel gasified. The heat absorbed in decomposing the carbon dioxide in this gas will be $10{,}050 \div 12.5927 \times 1.38 = 1101.4$ B.T.U. The net heat evolved in the producer is $4450 - 1101.4 = 3348.6$ B.T.U., and the efficiency is $(14{,}500 - 3348.6) \div 14{,}500 = 0.769$. The fol-

lowing table (III) shows the composition of the gas. The heat absorbed per 1° F. rise in temperature is

$$2.5885 \times 0.247 = 0.63936$$
$$4.953 \times 0.245 = 1.21349$$
$$\text{Total} = 1.85284 \text{ B.T.U.,}$$

and the elevation of temperature is $3348.6 \div 1.85284 = 1807°$ F. The gas contains the $2.5885 \div 7.541 = 0.3432$ part of carbon monoxide and the 0.6568 part of nitrogen. Its heating value is $(2.5885 \times 4315) \div 7.541 = 1479$ B.T.U. per pound.

TABLE III

CONSTITUENTS OF GAS PRODUCED FROM AIR AND WASTE EXHAUST GASES

Source.	Carbon, Lbs.	Oxygen, Lbs.	Nitrogen, Lbs.	Total, Lbs.
Exhaust gases	1.38 × 1/12.5927 = 0.1095	2.6667/12.5927 × 1.38 = 0.2920	8.926/12.5927 × 1.38 = 0.9785	1.[illegible]8
Fuel	1.00			1.00
Air: balance of oxygen needed for gasification		1.3333 − 0.292 = 1.041	77/23 × 1.041 = 3.485	4.526
Air: oxygen to gasify the carbon in the exhaust gases		1.3333 × 0.1095 = 0.146	77/23 × 0.146 = 0.489	0.635
Totals	1.1095	1.479	4.953	7.541
	2.5885 lbs. CO			

4315 ÷ 7.541 = 1479 B.T.U. per pound.

Comparisons, Steam vs. Exhaust Gas. The dotted lines of the chart, Fig. 1, show the results obtained from the use of varying proportions of exhaust gas. The temperature elevations being taken to correspond with those with steam, the efficiency curve is lower. The following may be noted:

(1) When using waste gas, no hydrogen is present in the gas. When using steam, the proportion of hydrogen increases with that of steam. In metallurgical furnaces, the presence of hydrogen in the gas is often advantageous, but with gas engines, the per-

missible amount of this substance is limited to that at which the gas will endure the desirable degree of compression without self-ignition. With 40 per cent of the oxygen supplied by steam, the percentage of hydrogen in the gas, as computed, is only 1.3 by weight; but even this small amount requires such lowering of the compression pressure as will noticeably affect the engine efficiency. The possibility of a varying percentage of hydrogen, when steam is used, is a far more serious matter. This has caused trouble in some suction gas plants, sometimes leading to proportions of hydrogen that were actually dangerous at the compression used. Occasional pre-ignitions reduce the efficiency greatly. It is claimed by Tait that a variable mixture of gases is also objectionable because of the differing speeds of combustion, that hydrogen burns twice as rapidly as carbon monoxide and that the time of ignition must be sufficiently late to coincide with the burning period of the hydrogen; and that the full benefit of the power of the carbon monoxide is thus not derived during the power stroke of the engine. The further claim is made that hydrogen is essentially unfit for use in an engine on account of the impact resulting from its quick ignition. These, it should be understood, are the claims of those who advocate the use of waste gas in preference to steam.

(2) With steam, the composition of the gas varies with the amount of steam used. With waste gases, there is no change in composition from that obtained when pure air only is used. This follows from the fact that we are returning to the producer, each time, the carbon originally charged to it, with oxygen and nitrogen in atmospheric proportions.

(3) With steam, the heating value of the gas varies, while with waste gases it remains constant. This is because of the composition of the produced gas, just referred to. Since the waste gases contain more inert diluent (nitrogen), the heating value, with waste gas, is less than that ever obtained with steam.

(4) The use of steam decreases the weight of gas produced per pound of fuel, while the use of waste gas increases it. Steam contains more oxygen than does air, while waste gases contain less oxygen than air.

(5) A stated elevation of temperature is attained by the use of a smaller quantity of steam than of waste gas. This is related to the heat of decomposition, the proportion of combustible in the compound, and the specific heats of its elements.

(6) The efficiency corresponding to a stated elevation of temperature is less with waste gases than with steam. The three factors just mentioned are also responsible for this result. The efficiencies are equal only when the percentages of steam or waste gas are zero, or in the limiting case when no elevation of temperature occurs.

Use of Waste Gases in Practice. Comparative tests as to the influence of steam and waste gas on engine efficiency have been made by Barrus (reported in Cassier's Magazine), who used compression pressures of 140 pounds with the former and 200 pounds with the latter. The corresponding engine capacities were 89.5 and 110.5 brake horse-power, an increase of 19 per cent in favor of waste gas. The combustible used per brake horse-power hour was 1.51 pounds with steam and 0.97 pound with waste gas, a saving of about 36 per cent by the latter. It would appear unfair to assume so large a difference of compression pressures as truly representative, and no generalizations should be based on these test results.

Fig. 2 shows the plant tested. The engine is a three-cylinder, vertical 100 horse-power gas engine, operated by a Wood suction producer. *A* is the producer, *F* the preheater, *C* the scrubber, *D* the purifier, *N* the water seal and *E* the blower for starting. *B* is the engine. The 6-inch exhaust pipe from the engine vents to the atmosphere at *L* or passes a portion of the gases through the 4-inch pipe shown in the end elevation to the ash pit of the producer. The fresh-air supply enters through the 4-inch pipe *G*. The pipe *G* is always fully open, while the gas intake *H* is partly closed. The steam generated in the producer jacket escapes to the atmosphere through the vent valve *K;* the valve *J* admits steam to the producer ash pit when desired. When using steam, the fresh-air supply enters the preheater at *M*, thence passing to the producer jacket, mixing with the steam and finally passing with the steam down the pipe *J*. No provision is made for the admission of preheated air with the waste gases, since the mixture of air and gases at *G* effectively raises the temperature of the former.

A somewhat similar plant has been installed in the works of the John Thompson Press Company at Long Island City, N. Y. In this case, as well as in that illustrated, the producer is of the suction type. A patent was issued nearly five years ago to H. L.

Doherty of Madison, Wis., embodying a method of using waste gas in a pressure producer. Fig. 3 shows the application to a coal-gas bench for the purpose of temperature regulation. In (*a*) is

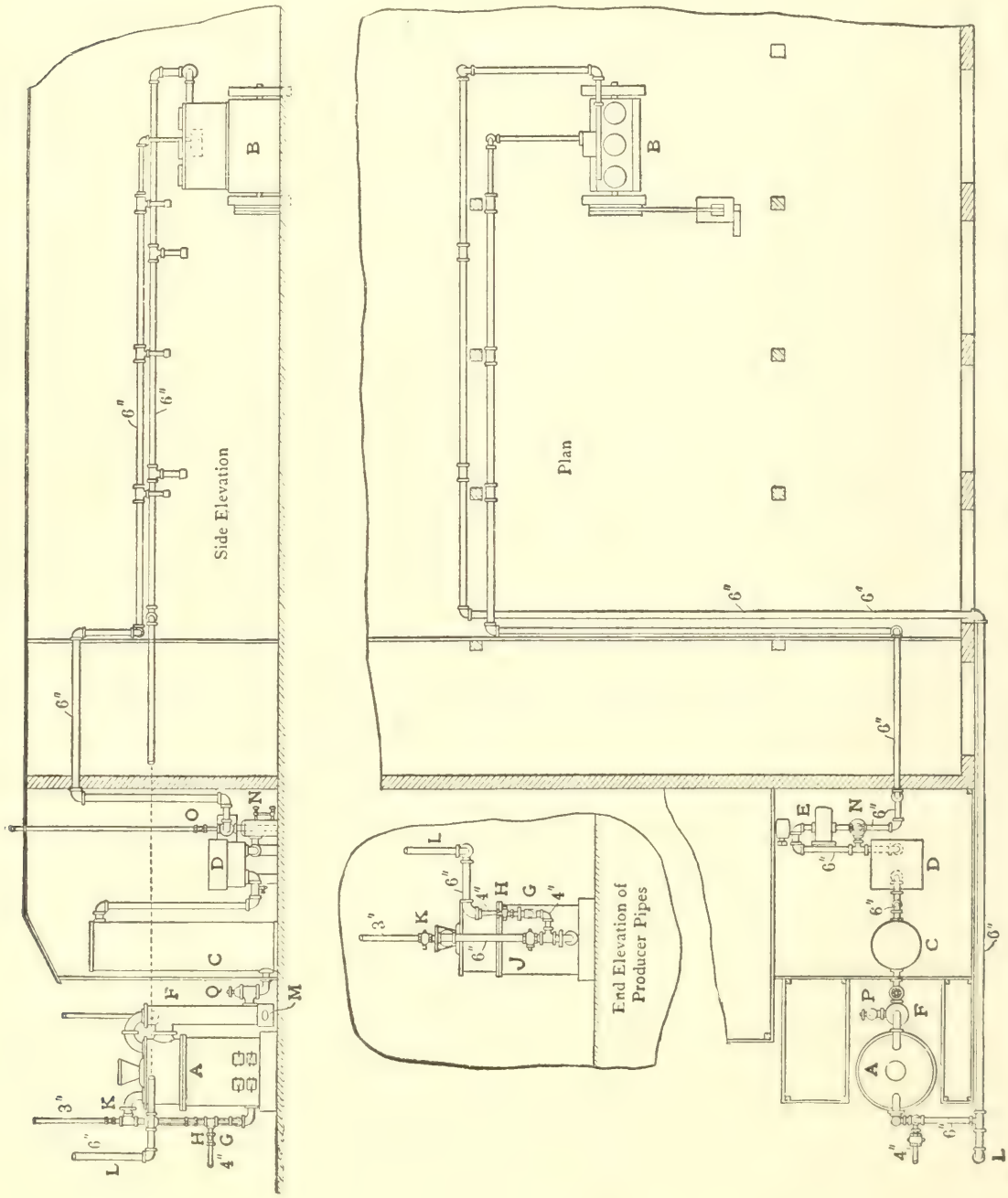


FIG. 2.—General Arrangement of Suction Producer Plant at Works of National Meter Company, Brooklyn, N. Y.

is given the front elevation of the oven, (*b*) is a vertical transverse section, (*c*), (*d*) and (*e*) are vertical longitudinal sections, and (*f*) shows one of the injectors used for drawing the products of com-

bustion from the waste flues and forcing them, mixed with air, under the producer furnace grate. The primary combustion chamber L is connected by a series of passages with the secondary

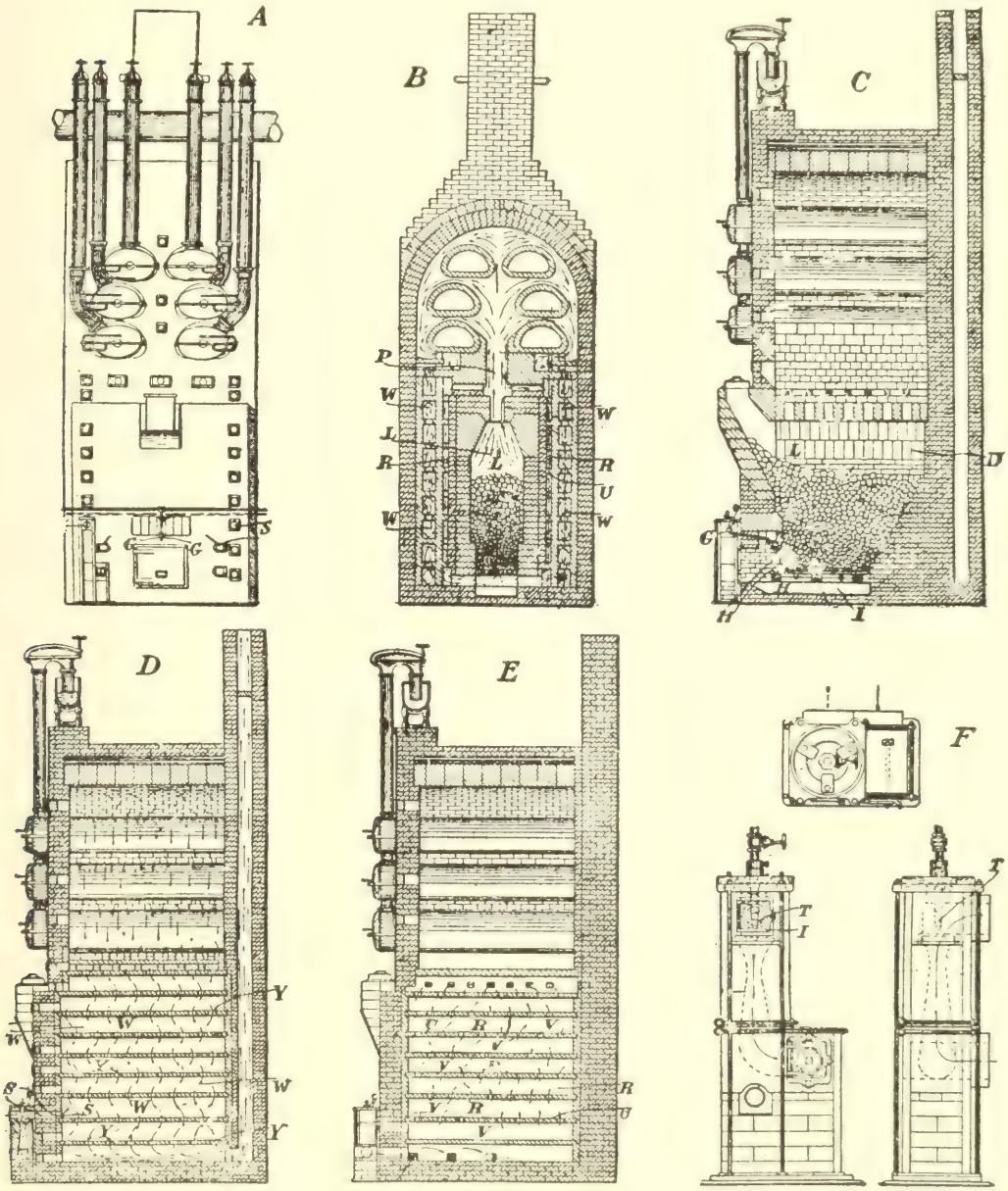


FIG. 3.

combustion chamber P, to which a separate supply of air is led. The secondary air flues R communicate with the atmosphere through dampers at the lower portion of the furnace. These and the waste flues W are so arranged as to form a recuperator. The

gases, after complete combustion in *P*, pass up and around the retorts, down through the waste flues and through a damper to the stack. By means of passages *S*, (*d*), in the wall of the bench, a portion of the gases in the waste flues is led to the air injector, (*f*), which discharges the mixed air and waste gas to the ash pit.

The use of either steam or waste gas reduces the tendency toward clinkering. The formation of clinker is related to the character of the non-combustible portion of the coal and to the temperature in the producer. Ordinary coal ash does not fuse appreciably at temperatures below 2000° F. When air alone is uesd for blast, the high producer temperature attained may form the ash zone practically into one solid clinker. When either steam or waste gas is used, the temperature is usually too low for serious clinkering to occur with ordinary coals.

For anything like satisfactory regulation, the supply of steam and of air should be kept constantly in a definite ratio. This ratio is to be determined in advance, and will be usually about 0.06, by weight. If the ratio is allowed to change, the engine capacity will be injuriously affected, as well as the producer efficiency. If waste gases are to be used, there is a ratio of waste gas to air at which the temperature reaches a minimum and the producer efficiency a maximum: the ratio is about 0.32 by weight. In this case, however, it need not be fixed in advance, since the composition and heating value of the produced gas are unaffected by variations in the proportion of waste gas used. Economical adjustment may be made after the plant is running.

Practical Modifications. The charts and comparisons here presented are based upon certain simplifying assumptions. The extent by which these assumptions depart from actual practice must be considered before formulating any general conclusions.

1. Some heat is always lost by radiation and by waste of fuel in the ash. It is difficult to say just what this amounts to. Actual tests have shown hot-gas producer efficiencies exceeding 0.90; so that the losses mentioned could not have exceeded 0.10. Possibly 0.05 is as low a loss as may be expected. The figure will be the same for steam as for waste gas.

2. The question of power for operating producer auxiliaries has not been considered. The efficiency of a steam boiler is not affected, as generally understood, by the amount of power required to drive the feed pump; but if the producer is necessarily

more economical or more extravagant than the boiler in its consumption of auxiliary power, the fact should be regarded in comparing the efficiencies of the two. The producer uses a fan or blower for moving the gas, power for delivering water to the scrubber, etc., for driving centrifugal purifiers, and sometimes for revolving the grate or for providing mechanical agitation for the fuel bed. Steam must be generated and coal must be handled. In the suction producer, the blower runs so rarely that its power consumption is negligible. Steam may be produced by waste heat. Handling coal is expensive in proportion to the amount handled, which, for a given output, is about the same with the producer as with a steam boiler. Comparing steam and waste gas, there is no difference in auxiliary power consumption when the producer is of the suction type; and the power required for driving an air injector is so small that when waste gases are used with pressure producers the power item is of no consequence.

3. The calculations for rise in temperature have been based upon the usual values for specific heats of the gases, considered as constant. It is known that the specific heats of the gases increase with increase of temperature. For carbon dioxide, for example, it has been shown by Åkerman that the specific heat is 32 per cent greater over a temperature range from zero to 2200° F. than over the range from zero to 750° F. We have insufficient data to accurately modify the efficiency limits stated, but we have no reason to assume that with correct figures for the specific heats the comparison of steam with waste gas would be noticeably changed. Since, in both cases, the specific heats have been taken too low, then the elevations of temperature corresponding with stated evolutions of heat are higher than they should be; actual temperatures are lower; the limit at which the desired reactions will cease is reached with a smaller proportion of steam or waste gas than that computed. The efficiency, consequently, as here computed, is somewhat too high.

4. We have assumed the coal to be pure carbon; actual coals consist of fixed carbon with admixed incombustible matter and volatile hydrocarbons. The influence of the ash we may ignore. The hydrocarbons, however, introduce an important modification. They may be present in quantities as high as 30 per cent of the fixed carbon, in power producer operation. They should undergo no chemical change, but should be distilled off as in the

retort process, carrying their full combustible value to the engine. This is the condition of most efficient operation, to be approximated in practice. Actually, some of the hydrocarbons are burned to carbon dioxide and steam, evolving sensible heat and decreasing the heat of combustion of the gas. This is due to the existence of too high a temperature in some sections of the upper or distillation zone, and points to the necessity of a deep fuel bed, relatively cool at the top.

When this undesirable combustion is avoided, the producer efficiency, so far as the hydrocarbons are concerned, is 1.0. With hydrocarbon coals, the efficiency may be higher than 0.6931, the limit for pure carbon when air alone is used; and higher still when steam or waste gas is mixed with the air. Taking a coal containing 25 per cent of hydrocarbons, the ideal efficiency when steam is used becomes $0.83+0.17/4=0.8725$; and when waste gas is used, adopting the same limit of temperature elevation, it becomes $0.785+0.215/4=0.83875$.

5. The temperatures tabulated and charted are elevations of temperature above those at which the fuel, air and steam or waste gas were supplied. When air alone is used, the temperature attained might be 100° F. greater. Steam is supplied at an initial temperature of about 350° F., but the proportion of steam is so small that the average initial temperature is only slightly increased. Waste gas, however, leaves the engine at 1000° or 1200° F., and is used in such proportions as to raise the average initial temperature to at least 400° F. This permits of a temperature elevation about 250° less than is allowable with steam, and raises the limiting efficiency with waste gas to about 81 per cent.

6. It has been assumed that just sufficient oxygen need be supplied to satisfy the chemical valence of the carbon. In practice, however, it is always necessary to provide a surplus of oxygen. This, in turn, involves a surplus of nitrogen or hydrogen. We commonly find free oxygen present, along with considerable amounts of carbon dioxide. The existence of the latter means a tremendous loss. The short-circuiting of gas currents in the producer, local variations in temperature and irregularity in the composition of various portions of the fuel bed, account for the imperfect reactions of practice. No producer gas is ever made without the formation of at least a small amount of carbon dioxide. For this reason alone, actual efficiencies can never reach those computed.

When steam or waste gas fails to decompose completely, the result is that the introduction of a definite amount of one of these substances reduces the temperature to a less extent than we have computed. The high specific heat of superheated steam tends, however, to keep the temperatures down more nearly the normal. In either case, failure to decompose necessitates bringing in an additional supply, weakening the gas. Moreover, the additional supply must be heated; a stated evolution of heat will raise the temperature of the whole gas product less; the temperature limit of efficiency is reached at a higher heat evolution and consequently at a lower efficiency. The comparison is slightly unfavorable to steam, on account of its high specific heat. In either case, the efficiency of practice is appreciably reduced below that theoretically computed. It is known that even at normal producer temperatures a large proportion of the steam is undecomposed. How this proportion compares with that of undecomposed to total waste gas has not been observed. An important comparison might be made.

7. We have assumed the gases discharged from the engine to be carbon dioxide and nitrogen. Again we are dealing with perfect reactions, unattained in practice. With a shortage of air supply to the engine, carbon monoxide will be found in the discharge. With a surplus, free oxygen will be present. In either case, the constituent with which we are concerned—carbon dioxide—appears in reduced proportions. More waste gas must be supplied to the producer then to accomplish a stated reduction of heat evolution; and if this be supplied, the temperature will be too much decreased. To keep the temperature at a proper figure, we must keep down the supply of waste gas (though above the normal rate) to that at which there will be a sufficient evolution of heat in comparison with the quantity of gas. The efficiency is thus reduced, as in 6. There is no corresponding loss with steam. With gases containing hydrocarbons, the steam combustion product from the engine is decomposed in the producer with the carbon dioxide, and the effect of their presence, briefly stated, is to cause operation with waste gas to become more nearly like operation with steam.

Limiting Efficiency as Practically Modified. The factors listed summarize as follows:

1. Losses by radiation, etc., will reduce the efficiency by probably about 5 per cent.

2. Power consumed by auxiliaries is not considered.

3. The high specific heats of gases at high temperatures make our computed efficiencies, based on constant values for the specific heats, too high.

4. The presence of hydrocarbons in the coal may raise the limiting efficiency with steam, to 0.88; and with waste gas, to 0.84.

5. The necessity for a surplus supply of oxygen reduces the efficiencies below those computed.

6. The use of excess oxygen in the mixture delivered to the engine produces the same result.

7. The higher initial temperature of waste gas increases the efficiency, when it is used, by about $2\frac{1}{2}$ per cent.

8. The formation of carbon dioxide in the producer lowers the efficiency.

Giving weights to 3, 5, 6 and 8 of a, b, c, d, then the practical limits of efficiency become,

for steam, $0.88 - 0.05 - a - b - d$,
and for waste gas, $0.84 - 0.05 + 0.025 - a - b - c - d$.

It seems certain that in either case the practical limit of efficiency is well below 80 per cent. with waste gas slightly inferior to steam. Actual tests of steam boilers have shown efficiencies as high as 83 per cent.

Composition of Gas, Computed and Actual. A reconsideration of the practical modifications of the ideal operations described shows that when steam is used we should expect to find in the gas less hydrogen than the amount theoretically computed, some carbon dioxide, undecomposed steam and hydrocarbons, and much more nitrogen. That this is precisely the case is shown by Table IV, p. 133.

The table shows an increase in the unlisted items of column 4 progressively from coke to soft coal, evidently on account of the increase in proportion of hydrocarbon in the fuel. For the same reason, the proportion of carbon monoxide shows a progressive decrease. The latter exists in larger proportions than were to have been expected with 20 per cent of the oxygen supplied by steam. Probably less steam than this was supplied. In each of the first three columns, actual practice gives results intermediate between those theoretically computed for no steam and for the maximum limit of steam.

TABLE IV

PRODUCER GAS COMPOSITION BY WEIGHT, USING STEAM

	Constituents, Percentages by Weight.			
	CO	N_2	H_2	Other.*
1. Theoretically computed, pure air alone being used	34.5	65.5	....	....
2.† Actually determined, with coke fuel, using steam	29.0	56.0	10.0	5.0
3.† Actually determined, with hard coal as fuel, using steam	25.0	49.5	20.0	5.5
4.† Actually determined, with soft coal as fuel, using steam	23.0	58.0	10.0	9.0
5. Theoretically computed, 20 per cent of the total oxygen being supplied by steam	21.4	32.7	45.9	....

* Water, carbon dioxide, and hydrocarbons.
† S. S. Wyer, op. cit., p. 51.

When waste gas is used, practical conditions should result in the appearance of free oxygen, carbon dioxide, an excess of nitrogen and a decrease of carbon monoxide. The following table confirms this:

TABLE V

PRODUCER GAS COMPOSITION BY WEIGHT, USING WASTE GAS

	Constituents, Percentages by Weight					
	CO_2.	O_2.	CO.	H_2.	N_2.	Other.
1. Theoretically computed, pure air alone being used	...	...	34.5	...	65.5	...
2. Actually determined, G. A. Barrus' tests *	1.8	1.2	26.2	0.4	69.7	0.7
3. Theoretically computed, any proportion of waste gas being used	...	...	34.5	...	65.5	...

* Reported in Cassier's Magazine, *supra*.

The hydrogen found in the test quoted may have been obtained from the decomposition of steam formed by combustion of hydrocarbons in the engine.

Conclusions. 1. The maximum theoretical efficiency attainable by gasifying pure carbon in pure air is 70 per cent. Fuels con-

taining hydrocarbons may be gasified at somewhat higher efficiencies. With pure carbon, and to a less extent with actual fuels, the efficiency may be increased by mixing with the air supply a proportion of steam or of waste gas from the engine exhaust. This action reduces clinkering.

2. The proportion of steam or waste gas must be kept constant for constant efficiency with a given fuel. Steam produces a richer gas than waste gas, but one the composition of which is variable. When waste gas is used, the composition and heating value of the produced gas are nearly uniform, regardless of the amount of waste gas used. Steam may make the gas so rich in hydrogen as to detrimentally influence the engine efficiency.

3. Various practical modifications lead to the conclusion that the maximum possible cold-gas efficiency, using steam, is under 80 per cent; using waste gas, it is slightly less at the same temperature limit than when using steam. Maximum efficiency is theoretically attained at a temperature of about 1740° F., when the proportion of steam to air by weight is 5.86 per cent; or of waste gas, 1.65 pounds per pound of fuel gasified. The heating value of the gas is then, with steam, 2000 B.T.U., and with waste gas, 1479 B.T.U. per pound.

4. Observations of the temperature of the produced gas furnish a good indication of the efficiency of operation.

5. A careful study of the rate of decomposition of steam and waste gas at temperatures below 2000° F. might show that a lower temperature limit and a higher efficiency are possible with the latter.

Discussion

Mr. Behr (Non-mem.):

The speaker has referred to the sensible heat which the gas carries off as loss. In practice, in some places, at least, the sensible heat is made use of for blowing the producer, and under some circumstances for blowing two or three producers. In the Roessler & Hasslacher plant over in New Jersey a boiler has been installed immediately after the producer. In that case the producer has been running over a year under these conditions, and has produced sufficient steam to blow two producers. Of course that would considerably reduce the so-called loss in question. Of

course this has no particular reference with regard to the real running of the producer itself, which has been so well treated in the paper. I thought that the point of loss might be of interest.

WM. M. BOOTH:

What is the dissociation temperature of oxygen and hydrogen?

W. D. ENNIS:

I should rather have some chemical engineer answer that question. One thing shown in the paper is that steam may decompose at various temperatures. It decomposes with extreme slowness below 1800° F. Only a fixed portion of the steam will decompose at that temperature.

WM. M. BOOTH:

This paper, as I understand it, treats the decomposition as beginning with steam. Suppose you began with water at 16°, what would then be your efficiency, using steam instead of air? It seems to me that you would have to account for that, because that water must be vaporized.

W. D. ENNIS:

The heat of decomposition is computed as more fully described in the paper; i.e., from steam at 350° F. to hydrogen and oxygen at whatever temperature is maintained in the decomposition zone of the apparatus. The H_2O is in practice supplied to the producer as steam—often as superheated steam.

WM. M. BOOTH:

Is not the theory of the use of steam the same as that underlying the application of the steam jet to a boiler?

W. D. ENNIS:

The steam jet is put under the boiler, not for chemical, but for mechanical reasons—to produce a draught.

WM. M. BOOTH:

It seems to me that you have to prove here that the efficiency is increased by using steam.

W. D. ENNIS:

I do not think it is necessary to prove that the efficiency is improved by using steam. Every gas-producer operator must know that.

WM. M. BOOTH:

The principle of the Cornell Economizer is that you can increase the efficiency by using vaporized water instead of air. Now is that true or not?

W. D. ENNIS:

In a gas producer?

WM. M. BOOTH:

No, in a boiler.

W. D. ENNIS:

I do not know. I am not familiar with the Cornell Economizer.

J. C. OLSEN:

If they used a limited amount of steam in a boiler, would not economy result, the same as in a gas producer?

W. D. ENNIS:

Not at all. In a steam boiler we are after sensible heat. It is as good as any other kind. In a gas producer we want to keep the heat of temperature down.

W. M. GROSVENOR:

Has any work been done to determine whether the percentage of steam it is possible to use may be increased by returning the sensible heat of the gases before passing out of the producer to both the incoming steam and the incoming air? As I understand the conditions the only limit reducing the possible steam below 20 per cent is the lowering of maximum temperature at what may be regarded as the central zone of the apparatus—the point of gasification. We say that the maximum amount of steam permissible is 10 per cent. Add steam, and the maximum temperature at the gasification zone is too much reduced and reaction becomes too slow. In contact process work, and a great many other chemical problems (the simplest illustration is the milk sterilizer working on the counter current-principle), a very slight added heat at the central zone is made to maintain the temperature by creating the differential between the two currents necessary to keep up the transmission from the outgoing to the incoming fluid. A very slight amount of heat is capable of raising the temperature to a very high degree. Has the same thing been tested in producer work?

If more steam than 10 per cent were added the temperature would apparently be reduced. But if both the steam and the incoming air were preheated to 100° it would be raised again. Would it not be possible then to maintain the zone of maximum temperature (the exit gas preheating the incoming gas) until 15 or 16 per cent of steam could be used?

W. D. Ennis:

It is a little difficult to say what per cent of steam might be used; certainly not 15 or 16 per cent, because then we get temperature elevations of only a few hundred degrees.

W. M. Grosvenor:

I do not think you would be getting any lower temperature, because you would return to the incoming gases all the heat (less a narrow margin for radiation) which was originally generated.

W. D. Ennis:

The margin is considerable. It is a common difficulty in recuperation apparatus to get the desired equalization of temperature. It is very seldom that the gas can be cooled much below 600° F., on account of the slow transmission experienced with a low temperature differential.

W. M. Grosvenor:

In "transferrers" used for contact work the differential does not have to be very great.

J. W. Richards:

I wish to congratulate the Institute, if I may, on the first paper read before it being a paper which deals with the quantitative side of industrial operations. I think that is a field where the pure scientists and the industrial scientists can come together for their mutual benefit.

I would like to make a few remarks as to the details of calculation, if Professor Ennis will permit. I noticed that Professor Ennis multiplies the weight of oxygen by 77/23 to get the weight of nitrogen. Multiplying the weight by ten and dividing by three will give the nitrogen more accurately. You can practically do it in your head, and the result is nearer to the correct proportion.

The specific heats of the gases are known to within a considerable degree of accuracy, and therefore the error introduced due to their

increasing specific heat can be taken into consideration. All that it means is about a ten per cent increase in a thousand degrees, and that amount can be accurately measured.

The professor has given the analyses of the gas by weights. I think that you will all agree with me that all analysis of gas is by volume, and therefore the calculations as to the possible influence produced are more understandable and more easily accepted if they are put in percentage composition by volume, instead of by weight. For instance, hydrogen gives a weight out in the fractions of a per cent, whereas by volume it may be eight, ten or fifteen per cent, and its influence upon the calorific value of a gas is directly in proportion to the volume present, and not according to the weight.

I would make a strong plea, gentlemen, for you chemical engineers to drop the British thermal unit as a standard; the Fahrenheit thermometer is the next thing, and, if possible, the pound is the last. But make a start on British thermal units. There are a great many reasons why you should do so, and if you will only take the British thermal unit first of all the rest will follow. The world, outside of the English-speaking world, uses the metric system, and their literature is not understandable to us, nor ours to them, if we use these units, and I think it is well for us to get in line with the majority of the rest of the world. If you use the British thermal unit you have a whole set of constants entirely different from the constants which we obtain by using calories. A compromise is possible, that is, if you will drop the Fahrenheit thermometer, and use Centigrade, you can use the unit pound-calory instead of the British thermal unit—the amount of heat necessary to raise one pound of water one degree Centigrade; then the constants used in the metric system are the same as in that system. If you are not willing to drop the pound, but will drop the Fahrenheit thermometer and will use the pound-one-degree-centigrade unit, all constants of calorific power are the same as in the metric system. You would therefore be able to get in touch with foreign literature and the foreigners in that regard. But it will mean still more to you. You will keep in touch with your own laboratory. Is there any laboratory that uses pounds, ounces, grains and scruples in its work? Of course there is not. We all use the metric system of weights and measures and the Centigrade thermometer in the laboratory. Is there any reason in your own

minds why you should stick in your works to the inadequate system of weights and measures of volumes and temperatures, and not adopt what your own laboratories for their own benefit have adopted? You certainly wish your works and laboratory to work together—what anybody else does does not matter—your laboratory and works ought to work in with each other. I do not think your workmen will give up their jobs because you require them to weigh in kilograms instead of pounds, or to read the Centigrade thermometer instead of the Fahrenheit. I might say that Mr. Dowson, one of the best English authorities on producer gas, I was very pleased to see, in his very fine book on producer gas, right in the citadel of English weights and measures, has adopted the metric system, and I am taking this opportunity to strongly urge on you commercial men, not only the advisability, but the profit and the ease of working that will accrue, if you adopt at least half way the metric system, and use calories instead of British thermal units.

Pres. Sadtler:

The matter cannot be discussed at very great length. If the allied matters were taken up it would mean all the rest of the day.

It is very probable that an opportunity will be had at some future date for a symposium prepared in advance by prominent chemical engineers, chemists and engineers, on some of these matters which Professor Richards has brought up. It would be very desirable to have a discussion arranged in advance upon some of those matters—as to whether we could make some changes to obtain more uniformity of methods of expression. That, however, is rather a far reach now, and we will not go into it at present.

W. D. Ennis:

The only reason for using percentages by weight instead of by volume is that the calorific values and specific heats are thereby more readily employed in the computations. The recent examinations of the specific heats of carbon monoxide and nitrogen do not appear to invalidate the conclusions advanced.

THE UTILIZATION OF LOW-GRADE FUELS IN THE UNITED STATES

By Dr. O. K. ZWINGENBERGER

Read at the Brooklyn Meeting, June 24, 1909

The United States Fuel Testing Plant at St. Louis and its branches at Pittsburg have certainly rendered a great service to this country in inducing the people to pay more attention to the economical utilization of coal. It has often been said, during recent years, that the exhaustion of our fuel supply will be in sight in a few decades and that a general revolution of our industrial and economic and public life will certainly take place. But revolutions do not come as suddenly as the lightning from heaven. They are all prepared in time, and the revolution to come in industrial life will be very well taken care of by the scientific men of the Geological Survey who are in charge of the fuel-testing plant. The work on the evaluation of coals for combustion under boilers and for utilization in gas producers was of great benefit to the development of industry, as is shown by the attention which gas producers and gas engines have attracted in recent time. The gas producer especially was given much attention at St. Louis and Pittsburg, as it is certainly the apparatus which, in combination with the gas engine, will in the near future replace, to a great extent, the steam boiler and steam engine for power purposes. This tendency is also greatly influenced by the centralization of power production and distribution. Nearly all the gas producers in this country are run on anthracite coal or coke, though attempts have been made to construct suction gas producers for power purposes which can be operated on bituminous coal and lignite. For metallurgical purposes a large number of producers are run on bituminous coal.

The United States Geological Survey at St. Louis tried all kinds of materials down to lignite and peat in boiler and gas-producer

tests. Though the results were most satisfactory, the inducements thus presented to the people in regard to these materials, and especially the latter, were generally overlooked, and are not yet made the basis of industrial enterprise, though, at closer investigation, the future of this material is a most promising one.

In Europe, much attention has been paid for many years to low-grade fuel. In middle Germany and in Scotland a highly developed industry for the dry distillation of lignite or brown coal and bituminous slate has been established. It is to be said, however, that these industries were not originally founded to get the fuel contained in this material, but more for the by-products. For instance, in the distillation of brown coal, the resulting coke was practically regarded as a nuisance, as its disintegration raised difficulties in burning it in stoves. It was only by the construction of special stoves that the situation of this industry was reversed and the coke made the main product. Conditions in regard to the distribution of fuel supplies abroad are very different from American conditions. The people have to endeavor to make the best of the raw material obtainable in their locality, and therefore many efforts were made to take advantage of the experience obtained in the distillation of lignite in other fields, as, for instance, in the coking of peat.

In the eyes of many people, this latter raw material is pretty poor stuff, not worthy of the least consideration. One cannot deny that its utilization presents difficulties on account of its high content of water, which in the original condition varies from 85 to 90 per cent. The drying of this raw material appears to be the easiest thing in the world, but the matter becomes serious on account of the necessity of handling of great volumes and of the enormous quantities of water which have to be evaporated at the least expense. For this, one has to rely mostly on the sun and air. That the drying of peat on a large scale can be done, is proved in several instances, and will always be successful if the full attention and control of business men is obtained. It is a great pity that one has to say that this has not always been the case, for often this apparently simple matter has been made the object of a stock-jobbing scheme. You will see by the sample of coke, which I take the liberty of passing around, that something effective can be done in this matter. You will note that this peat coke, which is made in one of the German works on

the system of Mr. Martin Ziegler, is as hard as any other coke. In its chemical composition it is fully equally to charcoal and it can replace it in nearly all cases owing to its hardness. The cost of production of one ton of this coke is about $2.00 to $2.50. The by-products which are obtained are the same as in the distillation of wood, though in somewhat different quantities, and besides this there are some by-products which are obtained in the distillation of brown coal or lignite. The two materials, lignite and peat, have been extensively used for many years to run gas producers in smelting works, glass factories, pottery works, etc. Although the use of peat is of course not so great, its use for gas-producer work is very well established in quite a number of plants. This is evident from the fact that in the province of Schleswig-Holstein a central gas power plant was erected to supply electricity to sixty communities lying within a circle of sixteen miles and all the power necessary is furnished by gas coming from gas producers run entirely on peat.

The use of low-grade fuel in the United States is still very small, if there is any at all, and this fact is certainly due to the wide distribution of fuel in the United States. In the East there is anthracite and bituminous coal, in the West and South oil, and at many other places there is a good supply of medium-grade coal. Where the presence of adequate fuel eliminates the use of low-grade fuel, it would be even more unpractical to utilize it for the manufacture of products such as paraffin, lubricating oils, etc., since these are obtained much more readily and in much greater quantities by the distillation of natural oil. This condition will hold good for the future, so that it would be useless to advocate a special coking process for lignite in Texas where the by-products of lignite, such as paraffin, hydrocarbon oils, etc., would have deadly competition from oil and the by-products derived therefrom.

It is therefore certain that the use of lignite in Texas, for instance, cannot be developed along lines which have already proved successful at other places. Since the chemical side in regard to by-products is better left out, if the use of lignite as a fuel comes in question, either briquetting or gasifying is the best solution of the problem of utilizing lignite. There is always a demand for fuel, and the gas derived from lignite is as good as that from anthracite, and it can be produced at such an extremely

low cost that it can compete with any material, even water and oil, for power purposes. What is said with reference to lignite holds good also for peat. States like Texas, Dakota, and Montana having enormous supplies of lignite, and Minnesota and Michigan, having great deposits of peat, are very much interested in the question of low-priced power. Owing to great distances, cheap power for transportation is of the utmost importance for the development of those States; and the question whether they may have this source of power may be answered in the affirmative, as we have only to apply to lignite and peat the experience already obtained in the utilization of these materials at other places.

Here I wish to say a few words about a method by which it has been often attempted to coke peat or lignite, and which never leads to any success, as the resulting coke always comes out in a disintegrated form. One has to consider that lignite, in the state in which it comes from the mine, carries a water content of from 25 to 40 per cent; and peat in its natural air-dried state has such a water content of 25 per cent. Many attempts have been made to coke peat in a furnace which, in its dimensions, is very similar to the Otto Hoffman oven. This latter is very long, has a height of about 6 feet and a width of about 20 inches. Now what takes place when you put a material of such a high content of water into a furnace, which according to its dimension, is evenly heated all over its surface, and the temperature of which is generally so high that in the inside a heat of about 1000° C. generally prevails? When such a coking chamber is filled, the water in the material is suddenly subjected to evaporation, and this development of steam is so vehement in its power that the brick of air-dried peat or lignite is inevitably blown to pieces.

Furthermore, the material shrinks very much, so that after a certain time there would be a hollow space in the upper part of the coking chamber so that heat conduction would be very poor, giving a very low output in regard to both time and quantity. After a certain time, therefore, one has to fill in a new charge of raw material, and even this second charge would still, after a certain time, leave a little hollow space which one has to fill up again (Fig. 1). Therefore when the lowest layer would be entirely coked, the middle layer would be only in a half-finished state and the upper layer would be in its first state of carbonization. This brief consideration proves that a horizontal retort of moderate

height will not be a suitable apparatus for coking raw material of such bulk as peat and lignite, and the upright retort is then left as the only means to carry out successfully a coking process for this material. The upright retort has been in use for a long time for the distillation of lignite, and the furnace used in this industry was subsequently adopted and greatly improved by Mr. Martin Ziegler for the distillation of peat.

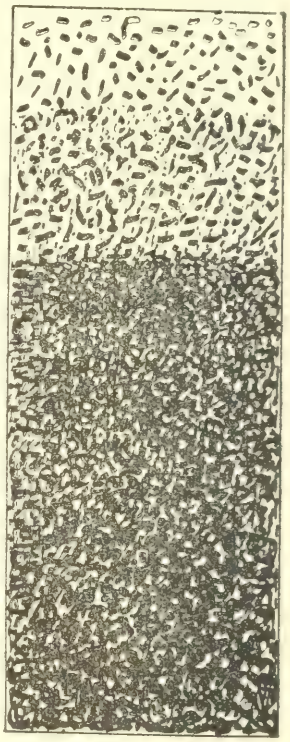


Fig. 1

The special feature of his process is the heating of the retort from the outside by two independent fire-places; the lower one gives the chamber an inside temperature of at least 1000° C. and the upper fire furnishes a heat of about 600° C. (Fig. 2). As the heat is not carried to the top of the retort the incoming peat meets, by radiation of the heat, only a moderate temperature. At intervals of one hour peat coke is drawn from the bottom of the retort and fresh material is filled in at the top. The material goes down to the bottom, step by step, and passes from the moderate temperature through the medium temperature and at the bottom is subjected to a high temperature. The effect of such a system is to produce a material retaining the original structure in which it was introduced to the coke chamber, though, of course, somewhat reduced in size by shrinkage; otherwise I would not be able to present to you peat coke in the form you see here. It may be stated that 95 per cent of the material comes out in the form in which it was introduced.

The gases produced in the coking process are passed through a condenser to remove the tar, etc., and the retorts are heated from the outside with this gas. As the supply of air with gas heating can be very accurately regulated, the outgoing flue gases are practically free of oxygen, and have a pretty high temperature. Mr. Ziegler constructed a special furnace which he fills with peat and into which he introduces these flue gases, and lets them pass directly over the peat (Fig. 2). The temperature of these flue gases is high enough to entirely carbonize the peat and deprive

it of the volatile matter. The resulting peat coke is, of course, not so hard as that coming from the retort ovens, but is still hard enough to stand transportation and handling and is equal

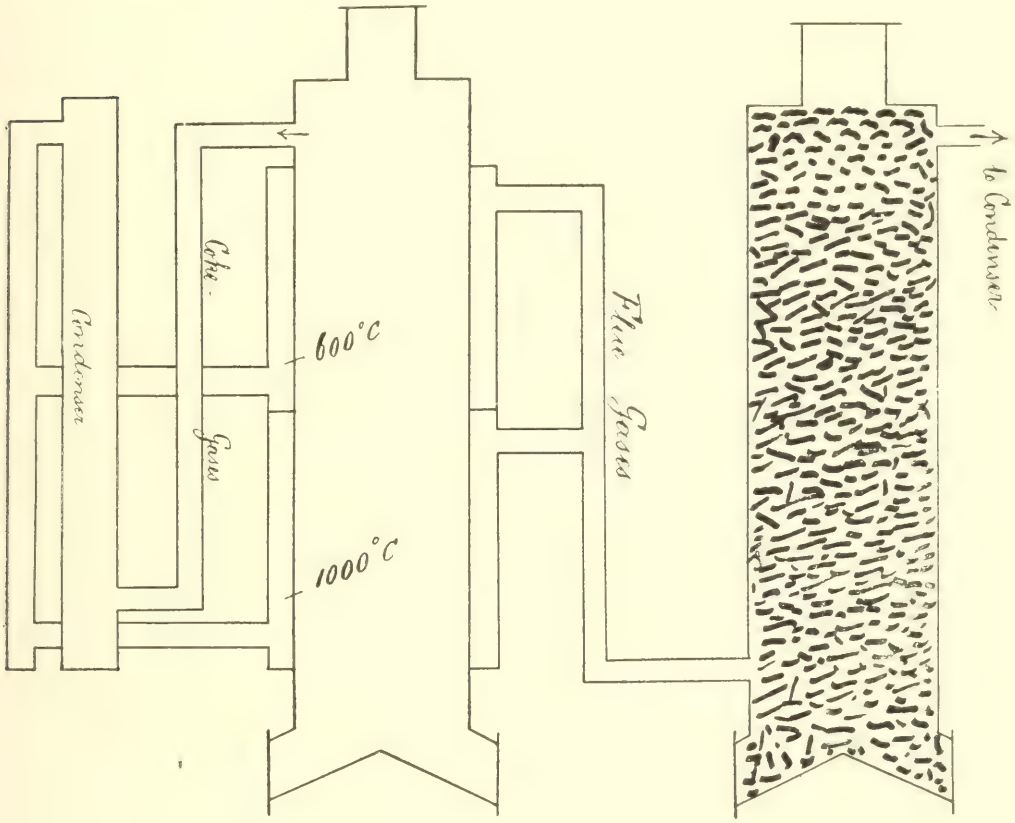


FIG. 2

in every way to the average coal. I give for comparison the analysis of peat coke, charcoal, and the lower grade of peat coke which may be called "half coke."

TABLE I

	Peat Coke.	Charcoal.	Half Coke.
C	87.8%	87.6%	73.89%
H	2.0	3.1	3.51
N	1.3	0.4	1.49
O	5.5	4.7	14.52
S	0.3	0.3	0.20
Ash	3.2	0.9	2.50
Water . . .	0.0	3.0	3.80
B.T.U. . .	14,500	14,500	12,100

You will see that there is hardly any difference between peat coke and charcoal and that the figures for half coke are good enough to stand the comparison with any good average coal. Now this success of Mr. Ziegler is of great importance for the rational utilization of lignite and peat under American conditions, for, by combining a gas producer with a coking chamber, a suitable apparatus is obtained and the results will be much better

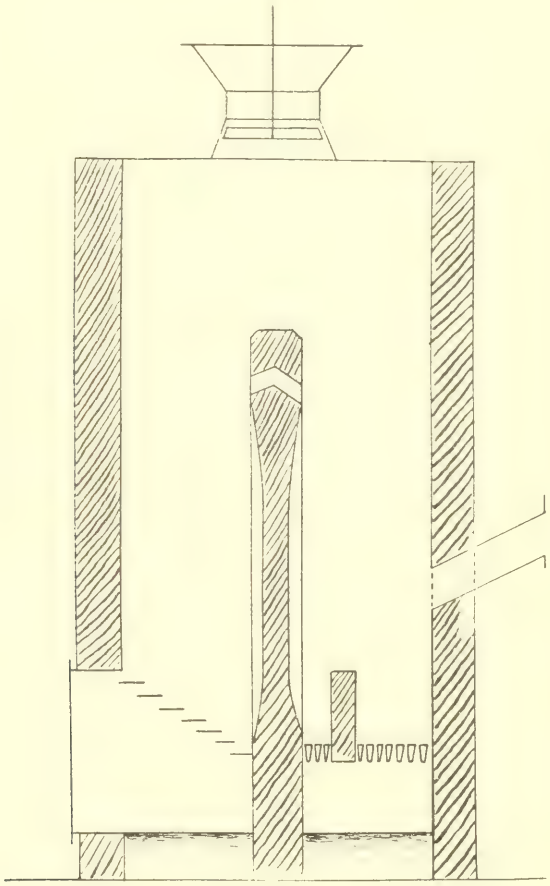


Fig. 3

for two reasons than the results obtained by Mr. Martin Ziegler's half-coke furnace. I may be allowed to allude to a construction of a gas producer on which I hold letters patent and in which, with some changes, this process may be carried out.

The gas producer (Fig. 3) is provided within its combustion chamber with a transverse partition which terminates at some distance below the top. This partition diminishes in thickness at the middle portion and is provided, in its upper thicker portion, with

transverse channels. An inclined step grate is arranged at one side of the partition to which air may be supplied under pressure by means of a supply pipe. The air passes to the fuel through the step grate after the fuel is ignited.

All the gases and tarry substances generated by the burning fuel go through the channels and over the partition into the other space where the fuel is dried and carbonized by the high temperature in the chamber. The gases, the tarry substances and the steam pass through the high column of glowing fuel, so that the tarry substances are decomposed while the steam acts on the glowing carbon. The heat generated in the chambers on both sides of the partition by the combustion of the fuel over the grate is sufficient to reduce the carbon dioxide to carbon monoxide while passing the glowing zones.

By this conversion of the tarry matter into permanent gases, and the reduction of carbon dioxide to carbon monoxide, the quantity of gas produced is increased, and, on account of the greater content of hydrocarbons, the heating value of the gas is also raised.

The efficiency of the present gas producer for peat as it is operated in Europe is already very satisfactory. There are a great number of such gas producers in operation in Sweden and in Germany. In the latter country there is one at Scheleken, erected by Mr. Ziegler, which burns 900 kilos or 1980 pounds of peat per hour, furnishing 2500 cubic meters of gas of about 1200 calories. Since $2\frac{1}{2}$ cubic meters of gas are required for one horse-power, this producer would run a gas engine of 1000 horse-power, but only the smaller part of the gas is used for power purposes. The main part is used in a Siemens-Martin oven in which scrap iron with proper additions is converted into steel; and, owing to the freedom of the flame from sulphur, the steel is of an excellent quality. The Scheleken Steel Foundry was largely increased in 1908. (See Transactions American Peat Society, 1908.) This producer at Scheleken is operated for the recovery of the by-products and has a condenser attached to collect the tar and the water. A large amount of ammonia is obtained in the form of ammonium sulphate, approaching about 50 per cent of the theory.

The gas producers for lignite and peat always produce tar, and according to the size of the producer, sometimes in considerable

quantities. This tar is of poor quality and has only a low market value. It is furthermore a troublesome nuisance, as it is the source of pre-ignitions in the gas engine, and of plugging the piston in the cylinder. These troubles are sometimes so obnoxious that they have led in one case to the shutting down of a 20,000 horse-power plant run on lignite. The condensing apparatus makes the initial cost of the producer relatively high, and the cost of running such a by-product plant in connection with a gas producer is also rather high, as the absorption of ammonia by the sulphuric acid and the concentration of the solution need careful attention. The pumping of sulphuric acid into the top of the tower is also troublesome. At remote places as in Texas, Montana, North Dakota, etc., the question of freight on sulphuric acid is also an item of consideration as well as the question of labor. At remote places only such apparatus is useful as guarantees by its construction and operation the greatest possible freedom from disturbances. One can therefore positively say that only big power plants using low-grade fuel should be operated for the recovery of the by-products. Plants under 1000–1500 horse-power had better drop the by-products entirely (provided there are not exceptionally favorable local conditions) and adopt a gas producer converting all the fuel into gas, by transforming the tar into volatile matter.

A reliable producer transforming all the fuel into gas is certainly the ideal apparatus for places where either lack of time or local conditions does not justify the recovery of the relatively small quantities of tar and the moderate quantity of ammonia.

The success of such a gas producer is guaranteed if one combines in it the features of coking with that of the gas producer. My gas producer as described above is designed on such lines and in its new form allows the production of a much better gas than is generally obtained in the old-style producer.

The change in the gas producer consists in dropping the second grate and in extending the second chamber *B* down to the bottom, thus making it more like a coking furnace so that it also furnishes coke (Fig. 4). Whereas in the gas producer the exit for the gases is at the side, in the new coking furnace the gases leave by quite another way, the exit for the gases being located in the lower part of the partition. The chamber *A* is run as a general gas producer; the gases passing over the partition *C*,

through the channels E, into the chamber B, in the upper part of which the heat of the gases is great enough to drive out the volatile matter of peat or lignite, the material being carbonized. We must now remember that in the old-style producer the tar is distilled off by the hot upgoing gases and is transported by them directly into the scrubber, where it is not sufficiently removed by water. In this construction, the part of the chamber B directly

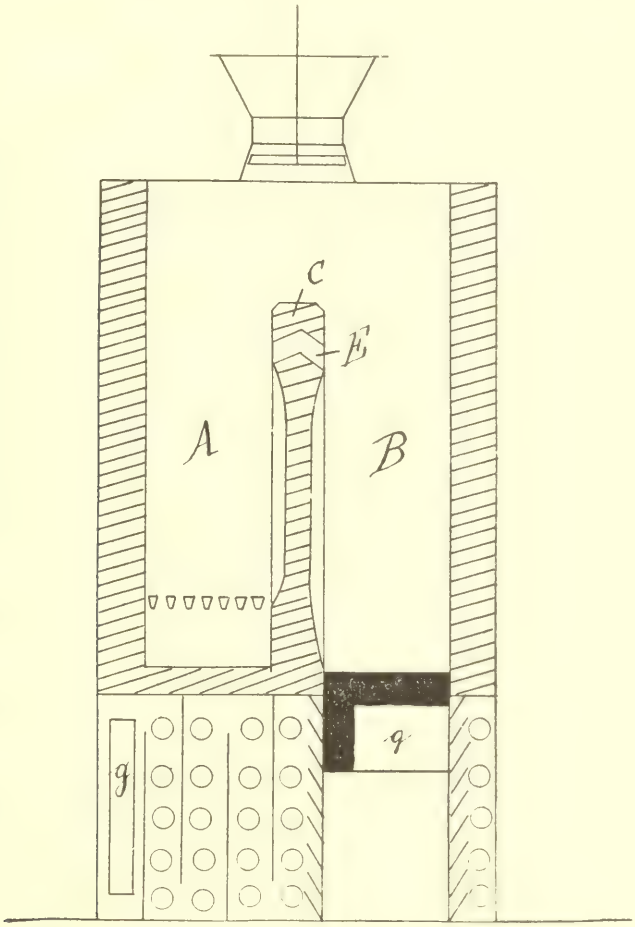


FIG. 4.—g, exit for gas; q, outlet for coke

adjacent to the combustion zone of chamber A, is so hot that the material is fairly glowing and transforms the tar into gas and reduces carbon dioxide to carbon monoxide. If we let chamber A become somewhat hotter, as is usually done with the gas producer, and approach somewhat the Dellwik-Fleischer process by blowing in air regardless of a larger amount of carbon dioxide, we will get in chamber A a great combustion zone of high temperature

and we will have in chamber *B* a temperature of 1000° C. Then the action of water on the glowing carbon will go on to the same extent as in the water-gas producer and the carbon dioxide will also be reduced to carbon monoxide on entering this hot zone. Of course, a part of the hydrocarbons of the volatile matter will be split up by this high temperature.

The special construction of this coking chamber admits of a feature which is generally difficult to combine with a coking process. That is, the cooling of the resulting coke and gas by water and recovering the heat contained in the glowing coke and gas. Fig. 4 shows a system of water tubes. The coke in sliding down will give a considerable part of its heat to the water in the tubes and, by partitions, the gas is made to zig-zag through these tubes in order to finally reach the exit. The system of water tubes is built out to a kind of a boiler or evaporator to supply steam to chamber *A* if this is to be operated as a regular producer.

Now let us come to the most interesting question. How many horse-power per hour can be produced from the gas as turned out by the coking oven?

The report on the work of the Ziegler gas producer, as mentioned above, is certainly giving results obtained with an exceptionally good quality of peat of very low ash content.

In the old-style producers one ton (2200 lbs.) of peat with 3 per cent of ash gives 2500 cubic meters, equal to 87,500 cubic feet of gas of 1200 calories, equal to 135 B.T.U. per cubic foot. Such a gas engine consumes about 90 cubic feet per horse-power hour. So that we get 87,500 divided by 90 equals 972 horse-power hours.

For the gas producer process it is not necessary to make fine peat bricks of about 10 inches length and 3 by 3 inches square, but loose masses dried in the open air will do, and may be taken in the calculation at $1.00 per ton, so that we have as the fuel cost for 1 horse-power hour $100 \div 972 = 0.103$ cent. In the Ziegler coking process one ton of peat with 25 per cent of water gives on the average 25 per cent gases weighing 1.104 gram per liter: 1 cubic meter = 1000 liters, weighs 1.1 kilo, and therefore we get from the total of 260 kilo gas.

$260 : 1.1 = 236$ cubic meters gas or $236.35 = 8.100$ cubic feet gas.

Besides the gas, there is also tar produced, generally between

4–6 per cent of the weight of the air-dried peat. This tar I will not include in the calculation, thus taking a more unfavorable standpoint than is offered by the actual conditions.

In this new form of coking we can coke in chamber *B* from 2 to 3 tons of peat on 1 ton burned up in chamber *A* and we therefore obtain besides the gas obtained in *A*, an additional gas volume of $8.100 \times 2 = 16.200$ cubic feet. But this gas generated in chamber *B* is much higher in heating value than that of chamber *A*, having 320–350 B.T.U. per 1 cubic foot, and so we obtain:

Chamber A: 87,500 cubic feet gas of 135 B.T.U.
per cubic foot..... = 11,812,500 B.T.U.

Chamber B: 16,200 cubic feet gas of 320 B.T.U.
per cubic feet..... = 5,184,000 B.T.U.
Total, 103,700 cubic feet..... = 16,996,500 B.T.U.

This gives 1418 horse-power hours; 1 ton of the peat burned in chamber *A* costs $1.00. The gas from chamber *B* is 25 per cent of the supplied peat, which costs $2.00. The total cost of the 1418 horse-power hours in fuel amounts to $1.50, giving 1 horse-power at 0.105 cent. It is evident that the addition of the coke gases to the producer gases is advantageous, the tar not being taken into consideration. I outlined this example on peat because I have had more practical experience with this material, but the conditions in regard to lignite are so closely related to those of peat that there will hardly be any change but that due to the different composition of the raw material.

Producers can be operated with lignite much more easily than with peat, as lignite contains about 10 per cent more fixed carbon. Its content of water is more uniform and therefore the relation between the steam generated and the resulting coke is much more favorable to the use of lignite than peat. When using the latter material this point must be carefully studied. The heating values of the peat gas alluded to with the Schelecken producer is somewhat low, but one has to consider that it is obtained with a peat containing from 30–40 per cent of water.

With a peat containing 25 per cent of water, a good producer will always furnish a gas of an average heating value of about 150 B.T.U. per cubic foot. The United States Fuel Testing Plant

obtained in one case with peat from Orlando, Florida, a gas of 170 B.T.U. If we take the additional heating value of the coke gases we will arrive at an average heating value of about 180–200 B.T.U. per cubic foot—a figure which never was and never will be obtained with anthracite or coke in the average gas producer.

By building a grate in chamber *B*, Fig. 4, of the same height as the grate in chamber *A*, the coking oven is transformed very easily into a gas producer in which it is possible to carry out a process which is nearly identical with the water-gas process and is also continuous. This point is of great importance, as until recently, such materials as lignite could not be used for a process similar to the water-gas process. There is no other change in the construction besides the building in of a grate. This grate stops the sliding down of the coke, the ash being removed through the opening through which one otherwise would draw out the coke, and the gas goes to the exit along the partitions in a zig-zag way striking the tubes and giving off the heat to the water.

It can readily be seen that a great deal of the steam is directly generated in both the coking chamber *B* and combustion chamber *A*. A great convenience afforded by the construction is evident from the sketch 5, which has two combustion chambers and one coking chamber. There is no doubt that the coking chamber *B* is much benefited by arranging the coking ovens in series, as then the influence of the heat of two combustion chambers is acting on one coking chamber *B* and the heat in *B* will then be most uniform. But it is not always necessary to have a series of such coking ovens, and in cases where a moderate unit only is required one can enjoy this benefit as outlined by sketch 5.

A furnace like that of sketch 5 is, for instance, most important for the generation of gas from bituminous coal for power purposes. Chambers *A* and *A* 1 are combustion chambers and supply the heat to chamber *B* in which the material is coked. Both chamber *A* and *A* 1 are constructed in the same way and a gas exit *g* 1 is provided for *A* 1. Sketch 5 is the mirror picture of sketch 4, if this be cut in two longitudinally through coking chamber *B*.

If a grate is built in as pointed out in Fig. 4, a continuous water-gas producer is obtained; steam may be applied through one or several supply pipes on top of the coking chamber *B*.

There is one principal difference in the present construction of my coking oven or gas producer contrary to all constructions

as far as I know. In nearly all other constructions the gas leaves the producer at the top or at the middle of the producer. The fact that the fresh material is added at the top of the producer is proof enough that in either case it must pass a moderately or medium hot zone where the generation of tar will take place or the transforming of the tar into permanent gas is not fully guaranteed.

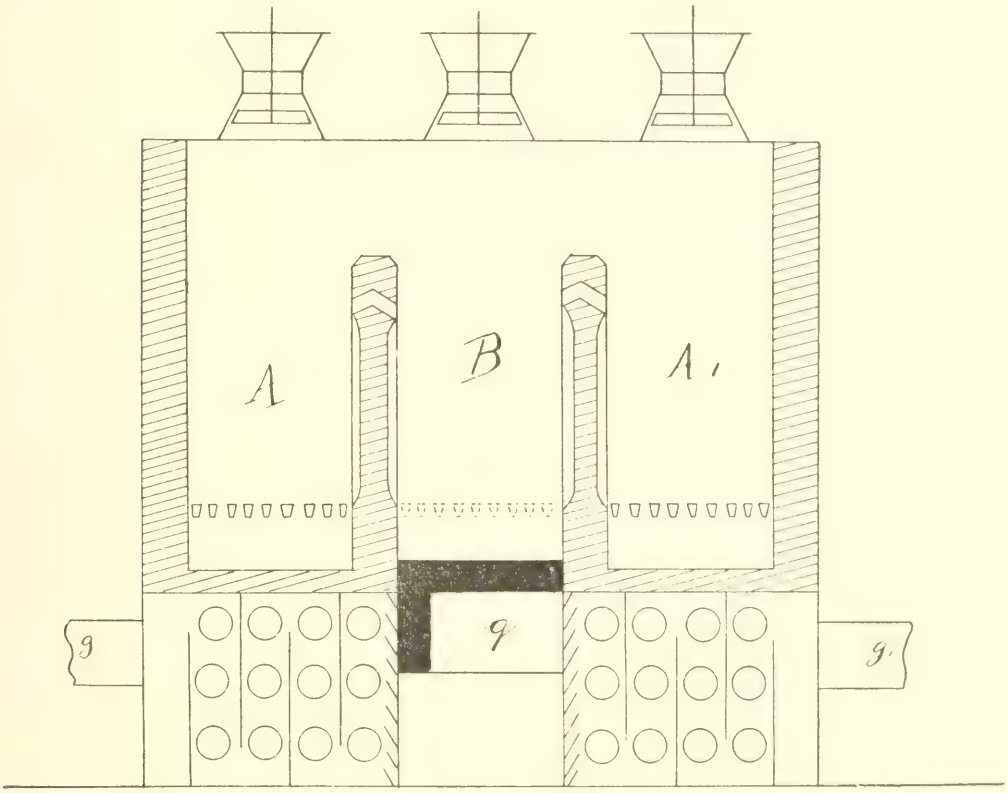


FIG. 5—$g = g_1$

My coking oven or gas producer has the great advantage that the tar generated and carried by the gas, contrary to all other constructions, passes first through the moderate zone and then through the medium hot zone, where a large part of it is transformed into permanent gas, and the small residue cannot escape decomposition because in leaving the producer it has to pass a zone nearly as hot as the hottest zone of the combustion chamber. This fact is of the greatest importance.

For the final conclusion, we may say that, according to the European practice, which is supported in the most successful way

by the exhaustive experiments of the United States Fuel Testing plants at St. Louis and Pittsburg, low-grade fuel is very well suited to furnish an efficient gas for power purposes and to furnish fuel in the form of coke which is equal to good average coal.

Furthermore, the extremely low price of 0.103–0.105 cent per horse-power hour fuel cost, is furthermore reduced by the addition of the gases resulting from the tar. The resulting coke, which will be from 30–40 per cent of the peat supplied to chamber *B*, will make up for the by-products as obtained by other constructions, and is certainly a more desirable by-product, as there is always a market for fuel but not for cheap and bad tar. The construction does not generally take into account the recovery of ammonia, but in case chamber *A* is run exclusively on conditions of the gas producer, the temperature in chamber *A* admits of the existence of ammonia, and so it will be well for larger units to consider this point. The construction as outlined here was especially designed for power plants under 1000 horse-power and to furnish a device rendering the operator, generally an engineer not so familiar with chemical problems, entirely independent of matters which he cannot fully understand. I have endeavored to show by reference to the by-products obtained, and the dangerous competition of oil with low grades of fuel, that there is generally only one feasible method of utilizing lignite or peat, and this is, as I hope I was able to prove to you, by gasification. The extremely low price of the power as to fuel cost can be realized from a simple form of construction of the apparatus and a low cost of attendance.

We are under obligation to the United States Geological Survey for a very conservative estimate of the peat supply in the United States and the highest credit must be given to Prof. Chas. A. Davis, expert in charge of the peat division, Geological Survey, Washington, D. C., for giving us reliable figures in regard to that point. All the peat in the United States suitable for coking has a value of $37,000,000,000, and there is still a great amount of this material which would not be suitable for coking but would be excellent for gas. One acre of peat land supplies about 200 tons of air-dried peat per each foot of depth and a peat bog of moderate extent furnishes material of both low and high ash content, so that a furnace such as I outlined utilizes the material high in ash in chamber *A*, whereas in chamber *B* coke is made from that

low in ash. That considerable interest has been awakened in the United States is evident from the formation of an American Peat Society, an organization especially formed to educate the people to the value of our low-grade fuel supply and to take the lead in the development of this coming industry on a sound basis, which according to the figures furnished us by the United States Geological Survey and the experience already obtained, seems worthy of the greatest consideration.

HEAT EFFICIENCY OF SMOKELESS COMBUSTION AND HEAT-ABSORBING CAPACITY OF BOILERS

By A. BEMENT, Chicago, Ill.

Read at Philadelphia Meeting, Dec. 10, 1909

This paper treats of two important features of the performance of steam-generating apparatus. The first deals with the efficiency of combustion in two representative cases of water-tube boilers, each served with chain-grate stokers and using the same kind of Illinois coal screenings.

The apparatus with which this first series of tests were made is shown by Figs. 1 and 2. Fig. 1 is the ordinary standard design of a well-known boiler, in which, before their combustion is complete, the gases from the fire pass directly among the tubes, with the result that smoke is produced and a loss of unburned hydrocarbon gases takes place. The purpose of the tests was to ascertain the loss of heat due to incomplete combustion under these conditions.

Owing to the lack of sufficiently exact apparatus, as well as uncertainty connected with accurate sampling, where hydrocarbons in small quantities are concerned, it was found after much experiment that the loss could be best determined by treating the boiler as a calorimeter and through it measuring the heat generated, which when referred to the original heat in the fuel, gave the measure of recovery, or in other words, the efficiency of combustion. In the employment of a boiler as a calorimeter, the correction for radiation is a serious and difficult matter, owing to the practical impossibility of its accurate determination in any direct manner.

The radiation factor, therefore, was obtained by difference with another similar steam-generating apparatus with which combustion was complete. The factor so obtained was then employed to represent radiation, which when subtracted from the

total unaccounted-for loss gave, by difference, that portion due to incomplete combustion. Thus, the unaccounted for loss of heat in the tests, including radiation, was 11.56 per cent. This, minus 2.26 per cent, the radiation factor, leaves a balance of 9.30 per cent, the loss by incomplete combustion.

The apparatus with which the radiation factor was determined is shown by Fig. 2, representing an improved boiler, arranged for the reception of a firebrick tile furnace roof, which as shown makes it necessary for the gases to travel to the rear of the boiler before

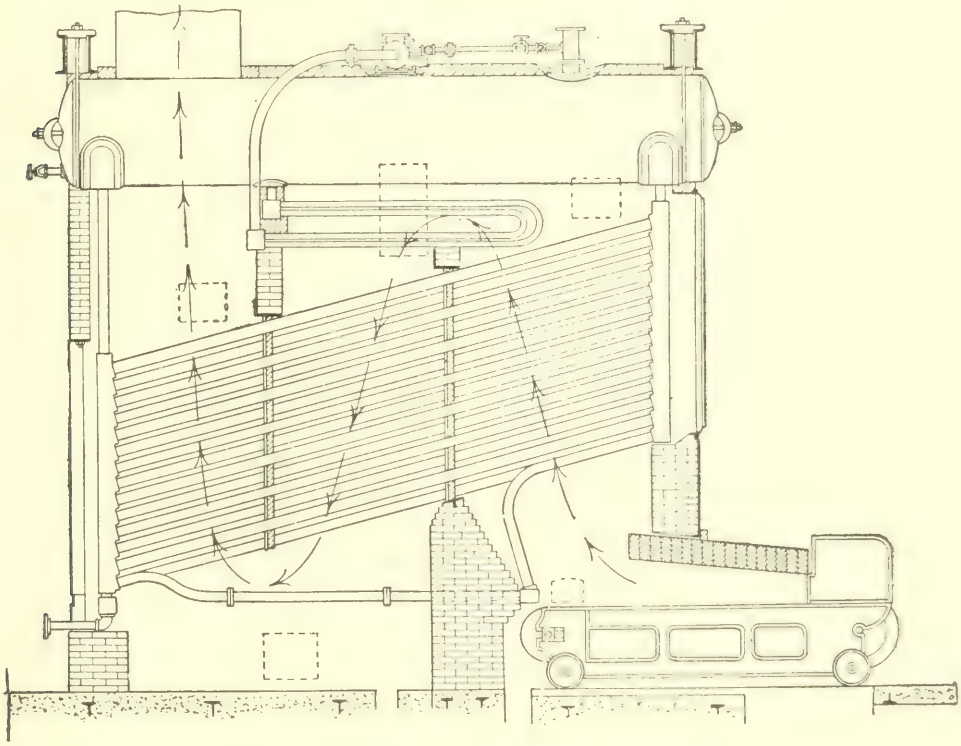


FIG. 1.—Ordinary Water Tube Boiler.

coming in contact with the water tubes. Not only did the results of tests indicate that combustion was complete, but the appearance of the chimney proved it, as there was no sign of smoke whatever.

The heat balance, Table No. 1, is based on four tests with the improved boiler and eighteen tests with the ordinary one.

The ordinary boiler is 18 tubes wide, 14 high and rated at 500 horse-power.

The improved boiler is 16 tubes wide, 12 high and rated at 400 horse-power.

The results of the tests with the improved boiler showed an unaccounted-for loss of 2.26 per cent, which included radiation. The opinion among engineers as to radiation losses range from one per cent to as high as five or six per cent, when boilers are worked at rated capacity. Both of these boilers were worked about 50 per cent above rating and it is probable that the figure is at least sufficiently high.

The setting shown by Fig. 1 was installed in Chicago and always produced an excessive amount of smoke for a stoker-fired

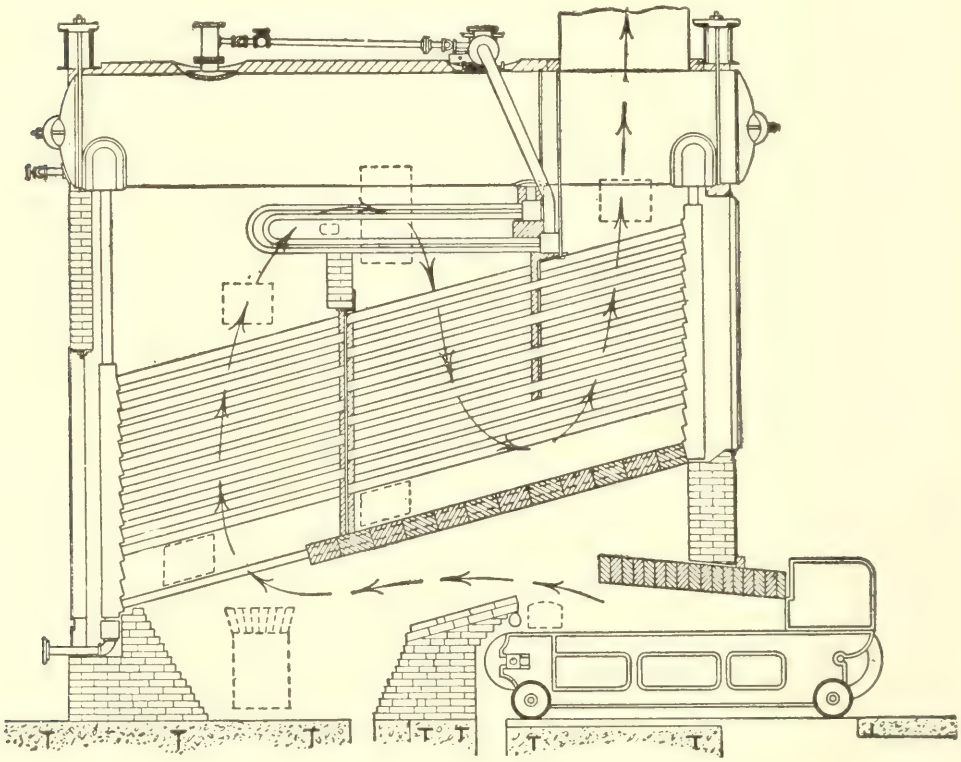


Fig. 2.—Improved Water-Tube Boiler.

apparatus. The improved boiler Fig. 2, was the first one installed at Cedar Rapids, Iowa, and was built to the author's design and specifications. For the purpose of the above mentioned tests, coal was shipped from Illinois to Cedar Rapids.

The roof of this improved boiler is composed of sections of tiles, so made that two of them encircle a tube in the lower row of the boiler so as to entirely cover it, sections being added in sufficient number to extend the roof to a point about three-fourths of the way from the front of the boiler to the rear. The shape

of the tiles is shown in Fig. 3. They were first employed in the Harrison Street electric power station of the Commonwealth Edison Company of Chicago and were devised by W. L. Abbott of that company.

TABLE I

COMPARATIVE HEAT BALANCE OF BOILERS AND FURNACES SHOWN BY FIGS. 1 AND 2

	Ordinary Boiler Shown in Fig. 1.	Improved Boiler Shown in Fig. 2.
Usefully employed in making steam	64.27	74.71
Loss in moist gases, due to		
Moisture in coal	1.39	1.68
Burning available hydrogen	3.22	3.24
Water of combination	1.37	1.31
Loss due to moisture in air	0.18	0.17
Loss in dry gases	17.86	16.48
Loss by radiation, by difference	.....	2.26
Loss by radiation, as a constant	2.26	.....
Loss by sensible heat in ash	0.15	0.15
Loss by incomplete combustion	9.30	0.00
Total	100.00	100.00

The following calculation shows in great detail the method of ascertaining heat loss in gases. The figures employed are taken from one of the tests of the improved boiler.* Treatment of the problem is very exact, much more so than in usual work of such character and for this reason it has been felt that this feature will be of interest. In this work two common errors have been avoided. The boiler test code of the American Society of Mechanical Engineers, Appendix XXXII, considers all of the fuel fed to the furnace as having taken part in the combustion process, with the result that calculations on this basis show an air supply larger than it actually is. The code also assumes that oxygen from the air is supplied for the total hydrogen of the fuel, when in fact it is necessary to oxidize only the available hydrogen. Both of these errors have a common effect, which is to make the air supply too large. The former, especially when fuel lost to the ash pit or over the back end of a stoker, is a considerable quantity, leads to quite serious results.

* Journal of the Western Society of Engineers, vol. 13, p. 209.

The data upon which the computations are based are:

Ultimate analysis of fuel and ashpit refuse. Heating power by Mahler calorimeter of fuel and refuse. Final gas temperature,

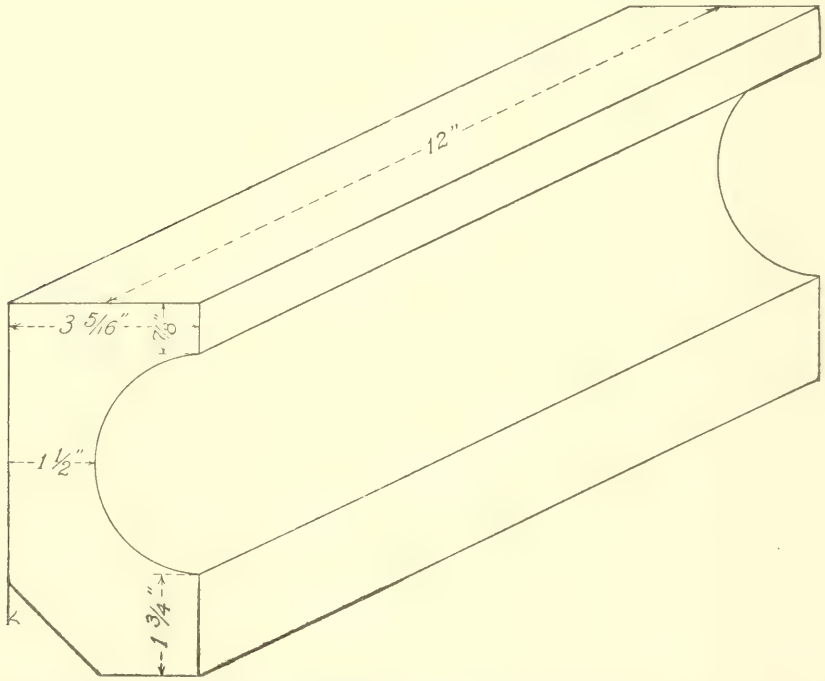


FIG. 3.—Tiles Employed in Formation of Furnace Roof of Improved Boiler.

which was 525.5° F. CO_2 by volume, which was 7.6. Temperature of air in boiler room, 85° F.

DETAILS OF COMPUTATION OF LOSS IN HOT GASES

ANALYSES OF COAL AND REFUSE

	Coal.	Refuse.
Moisture	14.61	.....
Ash	12.54	45.76
Carbon	54.54	48.33
Hydrogen, available	2.85	0.66
Sulphur	3.54	2.61
Nitrogen	0.90	0.67
Water of composition	11.02	1.97
Total	100.00	100.00
B.T.U. (by Mahler calorimeter)	10,332	7,522

DATA FROM TEST RECORDS

Coal fed per hour	3220.0 lbs.
Refuse per hour	687.7 lbs.
Refuse per pound of coal	0.214 lbs.
Boiler room temperature	85.0° F.
Flue-gas temperature	525.5° F.

FULL BALANCE

	Pounds per Pound of Coal.		
	Fed.	To Refuse.	To Gas.
1. Moisture	0.1461	0.0000	0.1461
2. Ash	0.1254	0.1254	0.0000
3. Carbon	0.5454	0.1034	0.4420
4. Hydrogen, available	0.0285	0.0014	0.0271
5. Sulphur	0.0354	0.0056	0.0298
6. Nitrogen	0.0090	0.0014	0.0076
7. Water of composition	0.1102	0.0042	0.1060
Total	1.000	0.2414	0.7586
8. B.T.U.	10,332	1,610	8,722

1. *Moisture:* All hygroscopic moisture fed to the furnace is evaporated and forms part of the flue gas.

2. *Ash:* The quantity of ash fed is the total ash of the coal. A certain portion of this is lost in the combustion chamber and in the slag on the bridge-wall and sides of the furnace. The amount of ash which is lost in this way may be obtained by subtracting from the total ash fed the ash found in the refuse which is weighed out from the ash pit. In this instance, it amounts to the difference between 0.1254 (lbs. of ash per lb. of coal) and 0.0979 (lbs. of ash per lb. of refuse) which is equal to 0.0275 lbs. ash.

3. *Carbon,* 4. *Hydrogen,* 5. *Sulphur,* 6. *Nitrogen,* and 7. *Water of Composition* were determined in the coal and refuse by analysis. The quantities of these constituents found in the refuse are deducted from the respective weights of carbon, hydrogen, etc., in the coal to obtain the quantities for the calculation of the flue gas composition.

8. The *Heat Value* of both coal and refuse were determined by the Mahler calorimeter. The difference represents the heat delivered by the furnace.

Loss Due to Heat Carried Away by the Hot Flue Gas

Composition of the Flue Gas

To calculate the composition of the flue gas, the weight of the various constituents of the coal which are given in the third column of the Fuel Balance under the caption "To Gas," are taken as a basis.

Carbon Dioxide

Carbon per pound of coal $\times 3\frac{2}{3}$ = lbs. of carbon dioxide. 0.4420 $\times 3\frac{2}{3} = 1.6206$ lbs. CO_2.

Carbon per pound of coal $\times 2\frac{2}{3}$ = lbs. of oxygen required for combustion. $0.4420 \times 2\frac{2}{3} = 1.1786$ lbs. O_2.

Sulphur Dioxide

Sulphur per pound of coal $\times 2$ = lbs. of sulphur dioxide. $0.0298 \times 2 = 0.0596$ lb. SO_2.

Sulphur per pound of coal $\times 1$ = lbs. of oxygen required for combustion. $0.0298 \times 1 = 0.0298$ lb. O_2.

Water

1. *From Available Hydrogen.*

Hydrogen per pound of coal $\times 9$ = lbs. of water. $0.0271 \times 9 = 0.2439$ lb. H_2O.

Hydrogen per pound of coal $\times 8$ = lbs. of oxygen required for combustion. $0.0271 \times 8 = 0.2168$ lb. O_2.

2. *From Water of Composition.*

Water of composition per pound of coal = 0.1060 lb.

3. *From Hygroscopic Moisture.*

Moisture per pound of coal = 0.1461 lbs.

Total Water in Flue Gas

1. From burning of available hydrogen	0.2439 lb.
2. From water of composition	0.1060 lb.
3. From hygroscopic moisture of coal	0.1461 lb.
Total	0.4960 lb.

Nitrogen

1. From nitrogen in coal	0.0076 lbs.
2. From air required for combustion.	
Burning carbon to CO_2	1.1786 lbs. oxygen
Burning sulphur to SO_2	0.0298 lbs.
Burning hydrogen to H_2O	0.2168 lbs.
Total	1.4252 lbs. oxygen

The proportion of nitrogen to oxygen in air, by weight, is 77 to 23.

Hence, $\frac{77}{23} \times 1.4252 = 4.7713$ lbs. Nitrogen from air required for combustion.

Total nitrogen $4.7713 + 0.0076 = 4.7789$ lbs. N.

The composition of the flue gas without excess air is then as follows:

Carbon dioxide	1.6206 lbs.
Sulphur dioxide	0.0596 lbs.
Water	0.4960 lbs.
Nitrogen	4.7789 lbs.
Total	6.9551 lbs.

The above gives the composition of gas without excess air. It is then necessary to determine the per cent of CO_2 by volume in the dry gas containing the above quantities of CO_2, SO_2 and nitrogen and from this figure derive the excess air for a flue gas of the 7.6% CO_2 composition as reported. As these gases follow the gas laws at ordinary temperatures, the respective volumes per cubic foot at 32° F. may be utilized in computing the percentage composition by volume.

	Wt. lbs.	Wt. per cu. ft.	Cu. ft.	Per cent.
Carbon dioxide	1.6206	÷.12268 =	13.210	17.72
Sulphur dioxide	0.0596	÷.17862 =	0.333	0.44
Nitrogen	4.7789	÷.07832 =	61.018	81.84
			74.561	100.00

Since the CO_2 in the flue gas as determined by the Orsat apparatus is the sum of CO_2+SO_2 in the dry gas, the dry gas composition by volume without excess air should be expressed as follows:

CO_2 (CO_2+SO_2)	18.16%
N	81.84%
	100.00%

There are two values for each, the CO_2 and nitrogen; one value in per cent of dry gas and the other in weight of each gas. The values 18.16 per cent and 7.60 per cent are both equivalent to the same weight of CO_2 (CO_2+SO_2); and similarly the nitrogen which necessarily accompanies the CO_2 is represented by 81.84 per cent and X per cent, both equivalent to the same amount by weight of nitrogen.

Hence, $18.16:81.84=7.6:X$, or $X=34.25$ per cent.

Then the composition of the flue gas containing 7.6 per cent CO_2 is,

CO_2 (CO_2+SO_2)	7.60%
Nitrogen	34.25%
Air	58.15%
	100.00%

The excess air is, therefore, 58.15 per cent by volume of the dry flue gas; and of the excess air 79 per cent is nitrogen and 21 per cent oxygen.

79 per cent of 58.15 = 45.94 nitrogen in excess air.

21 per cent of 58.15 = 12.21 oxygen in excess air.

The composition of the dry gas is then as follows:

CO_2 (CO_2+SO_2)	7.60
O_2	12.21
N	80.19
	100.00

The weight of CO_2 (CO_2+SO_2) in the flue gas is 1.6802 lbs.; nitrogen is 4.7789.

Hence, 7.6 per cent CO_2 is equivalent to 1.6802 lbs.

And 34.25 per cent N is equivalent to 4.7789 lbs.

The weight of nitrogen from excess air bears the same ratio to 45.94 per cent as does 4.7789 lbs. to 34.25 per cent.

Therefore, $45.94:x=34.25:4.7789$ or $x=6.4097$ lbs. nitrogen from excess air.

The oxygen from the air is found from the weight of nitrogen, thus, $\frac{23}{77}\times 6.4097=1.9146$ lbs.

The composition of flue gas with 7.6 per cent CO_2 is then as follows:

CO_2	1.6206 lbs.
SO_2	0.0596 lbs.
H_2O	0.4960 lbs.
N	11.1886 lbs.
O	1.9146 lbs.
Total	15.2794 lbs.

Loss of Heat in the Hot Gases

	Weight in Lbs. Spec. Heat Rise ° F.	B.T.U.
CO_2	$1.6206 \times 0.2169 \times 440.5 =$	154.8
SO_2	$0.0596 \times 0.1544 \times 440.5 =$	4.0
H_2O	0.4960 — see below =	616.6
N	$11.1886 \times 0.2438 \times 440.5 =$	1210.6
O	$1.9146 \times 0.2175 \times 440.5 =$	183.4
Total		2160.4

Loss Due to the Moisture in the Flue Gas

Raising 0.4960 lb. H_2O from 85° F. to 212° F. 0.4960×127	= 62.99 B.T.U.
Evaporating 0.4960 lb. H_2O from and at 212° F. 0.4960×965.7	= 478.99 B.T.U.
Superheating 0.4960 lb. H_2O from 212° to 525.50° F. $0.4960 \times 313.5 \times 0.48$	= 74.63 B.T.U.
Total	616.61 B.T.U.

Total Per Cent Loss on Basis of Heat Supplied

1. Loss due to dry gas $\frac{2160.4 - 616.6}{8722} \times 100 = 14.94\%$

2. Loss due to moisture $\frac{616.6}{10332} \times 100 = 5.97\%$

Total 20.91%

It is often desirable to obtain a value for oxygen and nitrogen in dry flue gas when the only constituent reported is CO_2, $(CO_2 + SO_2)$. A chart, Fig. 4, if drawn on squared paper with appropriate dimensions, may be used to obtain the percentage of nitrogen, and, under such conditions of combustion as produce neither CO nor hydrocarbons the percentage of oxygen may be derived by difference. In the test CO_2 only was reported. From the chart the percentage of nitrogen corresponding to 7.6 per cent CO_2 is found to be 80.03 per cent. The difference between the sum of the percentage of CO_2 and nitrogen and 100.00 per cent gives the percentage of

oxygen. The accuracy of this method is shown by the following comparative table:

	From chart	Computed
$CO_2(CO_2+SO_2)$	7.60	7.60
Oxygen	12.37	12.21
Nitrogen	80.03	80.19
	100.00	100.00

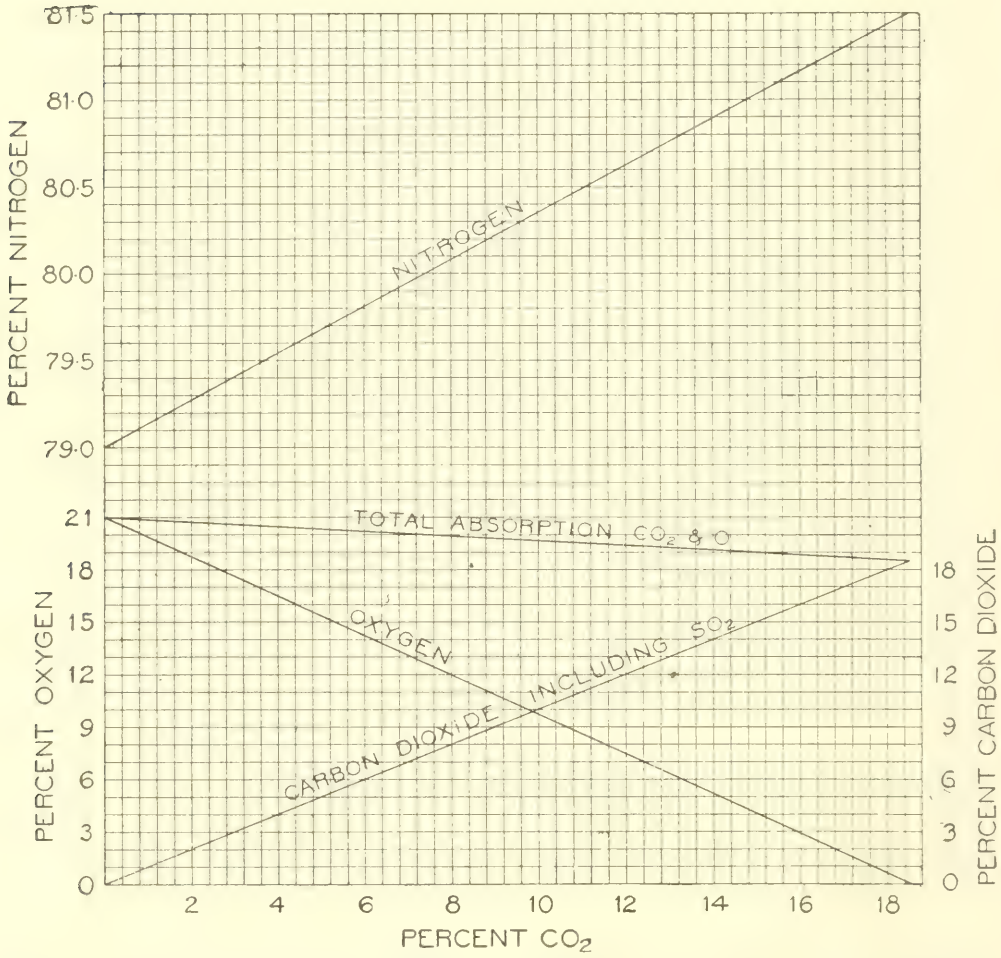


FIG. 4.—Diagram showing Relative Proportions in Gases from Complete Combustion.

The degree of accuracy of the results obtained from the chart depends upon the completeness of combustion. This particular chart would not be applicable to tests of coals differing greatly in composition from that upon which it is based, but data for similar charts may be easily computed from the analysis of the

various kinds of coal. As the total carbon content of the coal increases the sum of CO_2 and O_2 tends to approach the limit 21 per cent, so that, for 7.6 per cent CO_2 on a test of anthracite coal the oxygen would be somewhat greater than 12.37 per cent and the nitrogen be proportionally decreased.

The foregoing closes the first portion of the paper and the second may now be taken up.

The causes governing the efficiency of a steam boiler are not well understood and by the efficiency of a boiler is meant its ability to abstract the heat from the gases flowing over or though it.* But there are three principal elements, which may be enumerated as follows:

1. Form and design of gas passages, allowing the hot gases to come in contact with a greater or less amount of the heating surface.

2. Time in which the heated gases are in contact with the heating surface.

3. Velocity of the hot gases in their flow through, or, in contact with the heating surface.

The latter feature is one to which special attention has been directed by the researches of Messrs. Ray and Kreisinger of the United States Geological Survey. Thus far, however, it has not been possible to differentiate between these influences, nor to devise relative values for each. Experiments, however, have been made which show that not only is there a great difference in efficiency possible in different design,† but also illustrates how an efficient boiler differs from an inefficient one. As illustrated by the engravings, Figs. 5, 6 and 7.

Fig. 5 is a sectional view of a well-known water-tube boiler. It will be observed that the gases enter among the tubes at the bottom in the rear and find exit at the top at the front, traveling diagonally across the tubes to the exit. Thus it will be observed that this design conforms to the three foregoing requirements to only a limited extent. First, because the space being large,

* The boiler is a definite arrangement of heating surfaces, plus any fixed arrangement of gas baffles, which may be in use for the purpose of directing the course of the heated gases over the heating surfaces. This expression is quoted from Bulletin No. 31, Illinois Engineering Experiment Station, by C. S. McGovney, p. 12.

† Journal of the Western Society of Engineers, vol. 9, p. 44. Trans. American Society of Mechanical Engineers, vol. 26, pp. 419, 619.

velocity is low. Second, as the distance traveled is short, time of contact of gases with the tube surface is short. Third, as the path of travel of the gases is in a direct diagonal line from the entrance

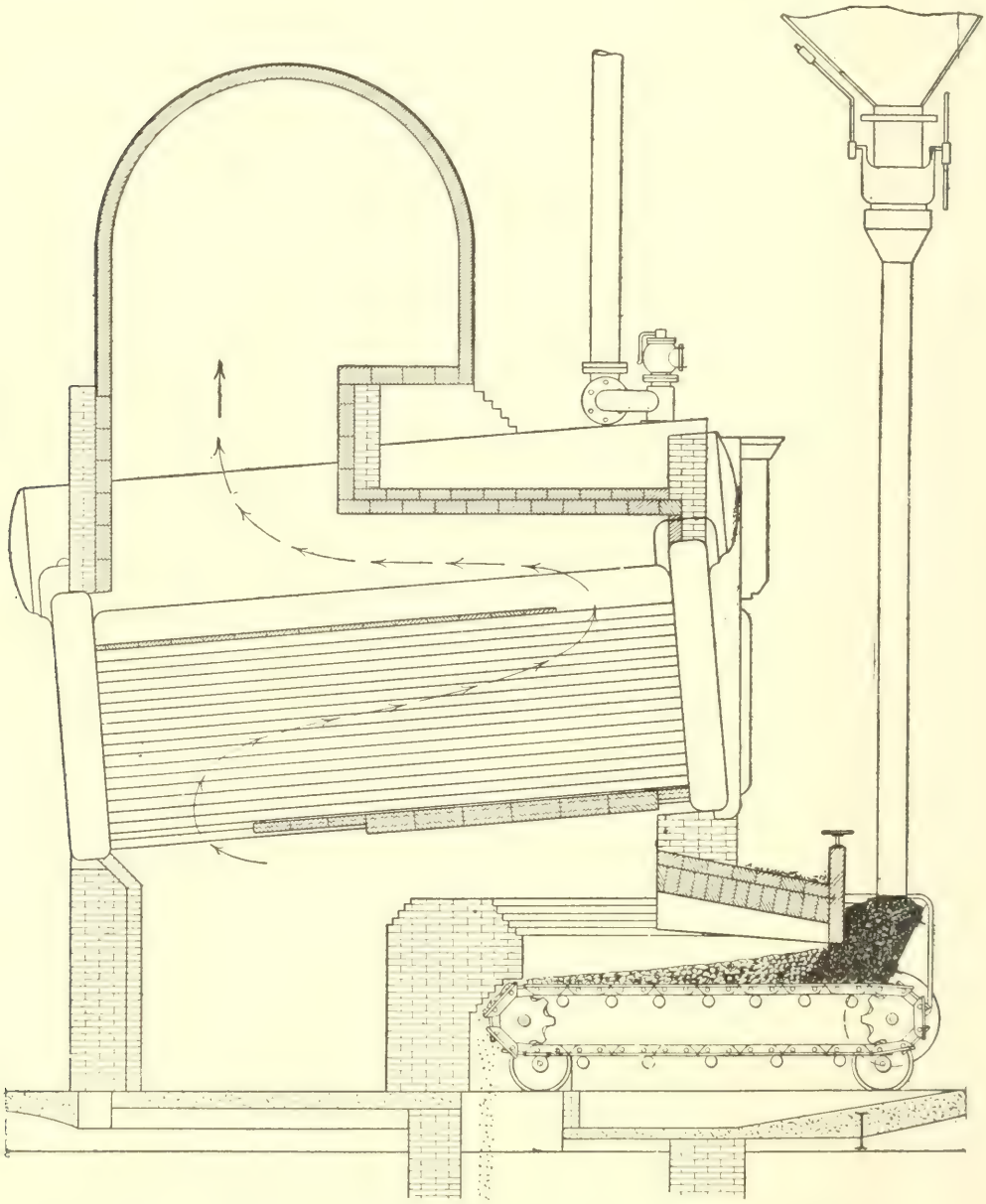


Fig. 5.—Water-Tube Boiler with Single Flow of Gases.

to the exit, heating surface in the top back corner and front lower corner perform little or no work.

For the purpose of increasing the efficiency of a number of these boilers shown by Fig. 5, changes were made as shown by

Figs. 6 and 7, which consisted in the insertion of baffles among the tube surface as indicated, causing the gases in one case to flow twice the length of the tubes and three times in the other, instead of only once as in Fig. 5.

The change shown by Fig. 6 caused more heating surface to be utilized, and the narrower passages necessarily increased the velocity of the gases, but as it only decreased the strength of draft

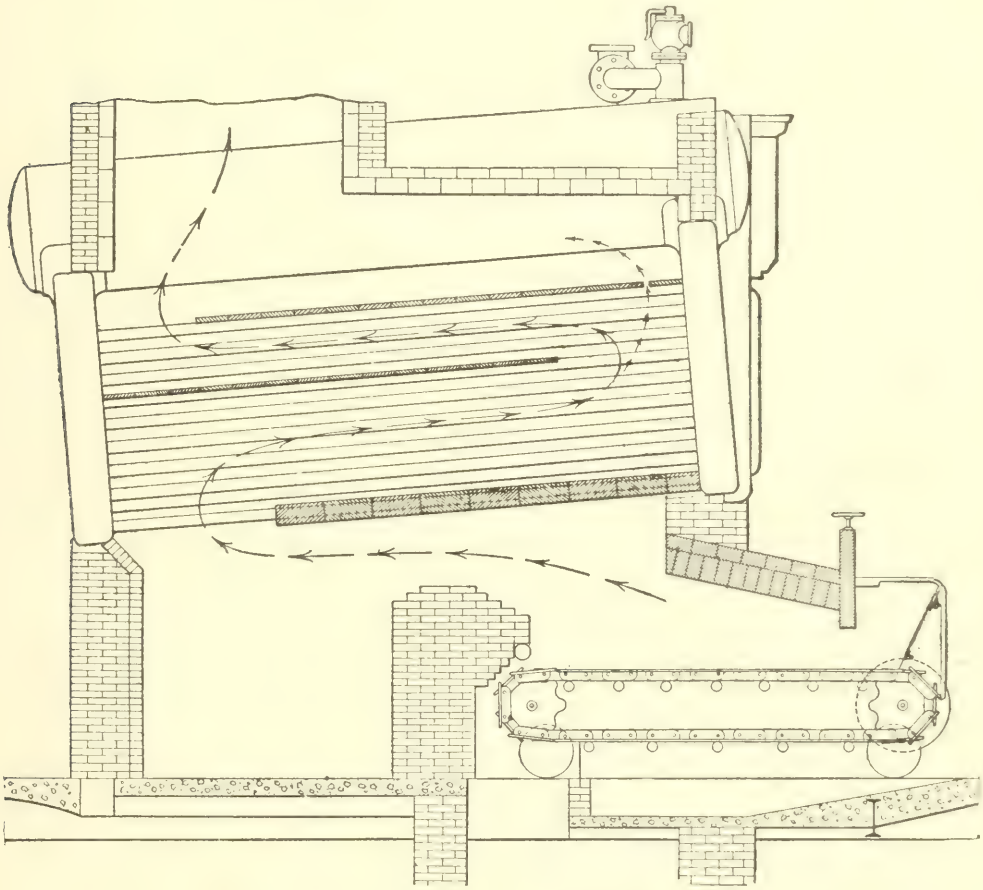


Fig. 6.—Water-Tube Boiler with Double Flow of Gases.

throughout the boiler by one-twentieth at the furnace, while the length of travel was nearly doubled, it necessarily follows that the time that the gases remain among the tube surface is greater.

With the design Fig. 7 the same features were developed to a greater extent on account of the triple pass. The velocity is correspondingly higher. A much greater amount of heating surface is utilized, the draft reduced by about one-third, while the

length of travel is increased by three times, so it follows that the gases are longer in contact with the tube surface.

Tables Nos. 2 and 3 present results of two sets of simultaneous tests between the single- and double-flow boilers in one case, and,

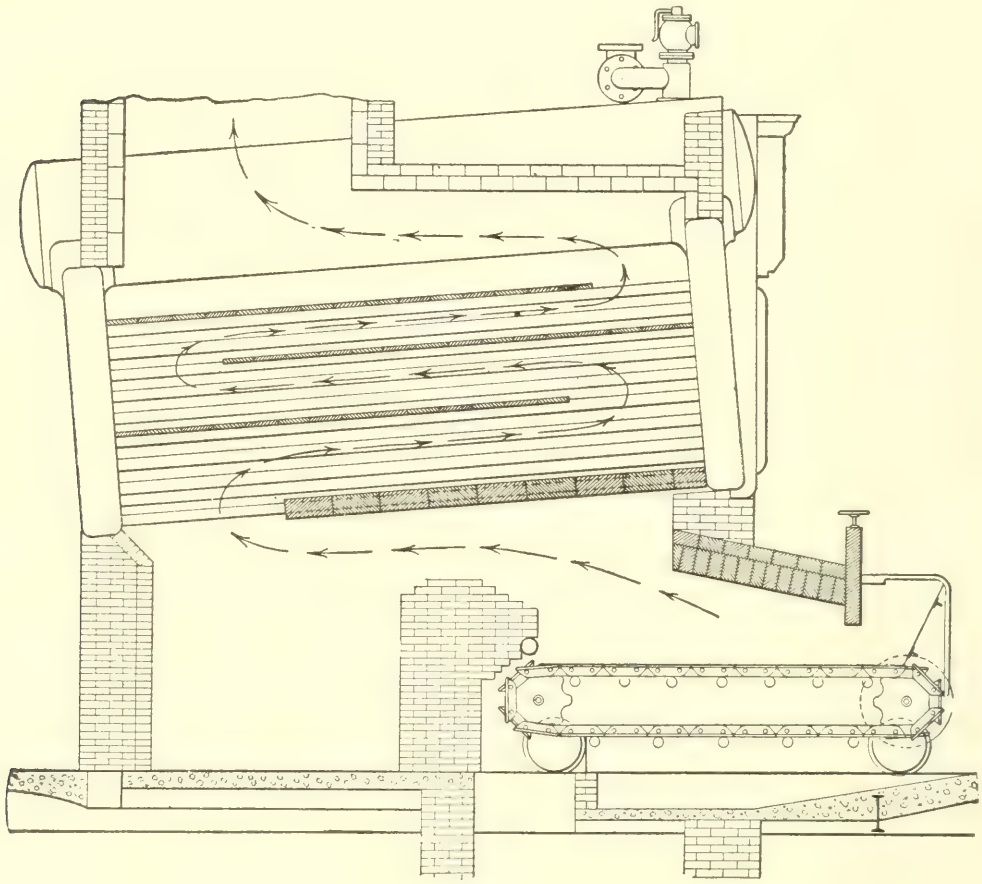


Fig. 7.—Water-Tube Boiler with Triple Flow of Gases.

triple flow in the other. Table No. 4 is from two individual tests made at different times and gives capacity and temperature measurements with single- and triple-flow boilers.

Table II

EVAPORATION TEST

Between Plain and Single-Baffled Boilers

	Single-Flow Boiler.	Double-Flow Boiler.
Pounds of pure coal burned per hour	2249.7	2152.1
Pounds of water evaporated per hour from and at 212° F.	18831.7	19720.4
Pounds of water evaporated per pound of pure coal burned	8.36	9.16
Heating power of pure coal B.T.U. per pound	14204	14204
Temperature of gases, final	643.7	605.9
Temperature of gases above steam temperature	265.7	227.9
Temperature of gases greater than baffled boiler ° F.	65.1	.....
Temperature of steam, ° F.	378.0	378.0
Furnace temperature, ° F.	2615	2583
Draft over fire, inches of water	0.41	0.39
Heating surface, square feet	4800	4800
Horse-power developed	545.8	571.5
Efficiency, per cent of heat absorbed by boiler	56.86	62.27
Fuel saving of baffled over plain boiler, per cent.	.....	8.68

Table III

EVAPORATION TEST

Between Plain and Double-Baffled Boilers

	Single-Flow Boiler.	Triple-Flow Boiler.
Pounds of pure coal burned per hour	1765.75	1446.56
Pounds of water evaporated per hour from and at 212° F.	13210.34	13629.24
Pounds of water evaporated per pound of pure coal burned	7.47	9.42
Heating power of pure coal, B.T.U. per pound.	13633	13633
Temperature of gases, final	594	442
Temperature of gases above steam temperature	217	65
Temperature of gases greater than baffled boiler, ° F.	152	.....
Temperature of steam, ° F.	377	377
Condition of combustion, CO_2 by volume	7.0	6.7
Draft over fire, inches of water	0.38	0.22
Heating surface, square feet	4800	4800
Horse-power developed	383	395
Efficiency, per cent of heat absorbed by boiler	52.93	60.73
Fuel saving of baffled over plain boiler, per cent	.....	20.68

Table IV

TEMPERATURE TEST

Of Plain and Double-Baffled Boilers

	Single-Flow Boiler.	Triple-Flow Boiler.
Condition of combustion, CO_2 by volume	10.7	10.3
Horse-power developed	564.3	580.4
Heating surface in boiler, square feet	4800	4800
Temperature of escaping gases, final	657	469
Tempearture of escaping gases, above air supply	582	394
Temperature of escaping gases, above steam temp.	278	92
Temperature of escaping gases, greater than baffled boiler	186	.....
Temperature of steam	379	377

Discussion

Mr. Dodge:

I would like to say that there are boilers made which I have seen worked in which the water in the boiler travels in the opposite direction to the flow of the gases continually, which to my notion seems to be a better way to have water flow to extract the heat from the gases, than to have the gases flow around and heat the hottest water with the coldest gas, which is the usual case in all boilers and in all leads, and I think that some such saving as is mentioned here is claimed for that particular style of boiler. It is a water-tube boiler, in which the water is fed into the top of the tubes and goes down by gravity to the lower tubes of the boiler and then to a steam drum above the water drum or maybe a steam drum in connection with the water drum. These drums are connected so that the foam, if there is any, goes back into the water drum. The advantages claimed are dryer steam, and no tendency to scale in the tubes, nearly or practically all of the scale being carried up into the steam drum, where it is removed when you want to clean your boiler. Also it has the advantage of being based upon a more scientific principle, that of having the coolest gases in contact with the coolest water, and the hottest gases in contact with the hottest water.

Mr. Wm. M. Grosvenor:

I was interested in figuring out a problem of just that kind. The velocity of transmission through the tubes is a function of two factors.

One of them is approximately the square root of the velocity of the liquid within the tube, the other the square root of the velocity of gases over the outside surface. The improvements outlined by Dr. Bement obviously take the greater possible advantage of the latter factor and the steeply inclined tubes of water-tube boilers take all possible advantage of the former. Any attempt to introduce the " cold " water at the tube and make it travel counter to the fire gases must not decrease the velocity of transition of the water through the tubes and thereby cause loss in efficiency of heat transmission, resulting either in higher temperature at the stack (low efficiency) or slow firing (small capacity). Neither of these can be compensated for by the gain of the counter current operation. A moment's consideration of the difference in temperature between cold water which in any well-organized plant is pre-heated from 170 to 250 and steam at 240 to 300 and comparison of this difference (70°) with the stack temperature desired for draught production will show how small is the saving we are looking for. If we were considering a pre-heater where the temperature of the entering liquid was to be raised 100 to 200 degrees, or if the design of the boiler is poor so that there is not rapid circulation producing a sort of film evaporation in the tubes, the case would be different, but maximum velocity of gas and liquid must remain the vital considerations in boiler design.

Mr. Dodge.

I was about to say that the water was passed counter to the gases on their way up to the stack. The water is passed downwards to the tubes, and flows in one direction entirely all the way. I have seen a small model made of glass tubes in which that was done. The larger boilers have been installed by the traction company of this city in several places. Some of them are fired at both ends and they get great economy.

Mr. Grosvenor:

Are the tubes vertical?

Mr. Dodge:

The tubes are horizontal, that is, inclined tubes. The water in the bottom row of tubes is practically all steam. I have seen it in the small model, where you can see that it is practically all steam. The foaming is taken care of by the water going up into the steam drum, which is connected with the water drum by a valve, which lets the water go down, but does not let the steam go back. Originally as designed, the boiler had check valves in the top end of the inflow tubes so that the water could not go back into the tubes, but it was found unnecessary. In the latter style check valves are entirely left out. There is a check valve between the steam drum and the water drum, and the water entrained, if any, goes back into the water drum. The first boiler was installed at the traction company's sheds at Chester. I saw the first boiler installed after it had been running on raw Schuylkill water for three months, and it was as clean as when it had been put in. It is the Parker boiler.

Mr. Herbert Hollick:

I know the boiler by name, but I do not know the diagram of it. I have heard of it as a very good boiler.

Mr. Dodge:

I know that the traction company thinks they are getting very good results from them. They installed them first at Mt. Vernon street at Wyoming avenue, and they have installed them at their new station at Beech street and Delaware River, that is double-ended Parker boilers.

CHEMICAL COMPOSITION OF ILLINOIS COAL AND RELATION OF HEATING VALUE TO COMPOSITION

By A. BEMENT, Chicago, Ill.

Read at Philadelphia Meeting, Dec. 10, 1910

Thus far but little published information concerning the Illinois coal field has been available. But recently a fairly comprehensive paper has been issued,* in which the various coal seams are discussed at length.

Some data on the chemical composition and heating power of seams will no doubt be useful. Therefore the following table is presented, giving moisture, ash and B.T.U. values of the coal as it is in the seam before mining and preparation.

CHEMICAL COMPOSITION OF SEAMS

Seam.	Fields.	Moisture.	Ash in Dry Coal.	Heating Power per Pound in B.T.U.		
				Moist Coal.	Dry Coal.	Pure Coal.
No. 1	All Fields	11.57	6.27	11,915	13,473	14,375
No. 2	Wilmington	15.34	5.87	11,514	13,613	14,462
No. 2	Northern	14.86	10.08	11,054	12,983	14,438
No. 5	Springfield	12.66	12.31	10,990	12,583	14,350
No. 5	Peoria and Fulton	14.67	15.10	10,381	12,166	14,330
No. 5	Saline	6.75	7.75	12,045	13,882	15,048
No. 6	All Fields	14.38	11.69	10,774	12,584	14,250
No. 7	Williamson and Franklin	9.65	12.16	11,508	12,737	14,500

The constituents in terms of pure coal of some representative seams are given as follows:

* Journal of the Western Society of Engineers, vol. 14, p. 308.

COMPOSITION OF SOME REPRESENTATIVE COAL OF ILLINOIS

	Seam No. 5, Southern.	Seam No. 7, Southern.	Seam No. 5, Central.	Seam No. 6, Northern.
Carbon	81.81	81.63	77.23	75.74
Hydrogen, available	4.24	4.02	4.02	3.63
Sulphur	2.04	2.14	4.45	5.24
Nitrogen	1.79	1.73	1.60	1.51
Water of combination	10.12	10.48	12.70	13.88

Pure coal, as will be understood, is ash- and moisture-free fuel, and the sulphur content is the remainder minus that remaining in the ash after combustion. The last table contains pure B.T.U. values for seams in different fields of the state.

PURE HEATING-POWER VALUES FOR DIFFERENT SEAMS AND COAL FIELDS

Coal Field.		Seam No.	Heating Power in B.T.U. per Pound of Pure Coal.
No.	Name.		
1	Rock Island	1	14,375
2	Northern	2	14,438
3	Wilmington	2	14,462
4	Peoria and Fulton	5	14,430
5	Grape Creek	6	14,140
6	Springfield	5	14,350
7	Virden	6	14,145
8	Pana	6	14,225
9	Central Illinois	6	14,240
10	Centralia	6	14,390
11	Duquoin	6	14,360
12	Williamson and Franklin	6 or 7	14,350 to 14,650
13	Big Muddy	2	15,075
14	Saline	5	15,048

There is a question whether the seam operated in the Williamson and Franklin county field is number six or seven.

As this is a brief paper it may not be out of place to call attention to the fact that the contents of these tables represent a very large amount of work.

CREOSOTE OIL FROM WATER-GAS TAR

By SAMUEL P. SADTLER

Read at the Brooklyn Meeting, June 24, 1909

It is stated in a Bulletin of the Forest Service of the U. S. Department of Agriculture about to be issued that more than 56,000,000 gallons of creosote oil were used last year in preserving timber in the United States. Of this amount 69 per cent was imported and 31 per cent was obtained from domestic sources. These figures are based upon reports to the Service of forty-four firms which operated sixty-four timber-treating plants.

The only other timber-treating agent in practical use was zinc chloride, of which 19,000,000 lbs. were said to have been used.

Both are excellent antiseptics and are commercially available. The principal point of superiority of creosote lies in its insolubility in water. Zinc chloride, being soluble, will leach out from timbers injected with this salt if the timbers are exposed to moisture. Moreover, creosote is the only material which will effectually protect timbers submerged in ocean waters from the teredo, or common ship worm, which works such havoc among the wharves of the Atlantic, Gulf and Pacific coasts. If properly injected, it cannot wash out, and is hence superior to any mere external coating. Let us therefore dismiss all consideration of any other material than creosote oil and turn to the consideration of this substance. What is it? Allen* says: "*Coal-Tar Creosote Oil* commonly consists of that portion of coal tar which distills between 200 and 300° C., together with the residual oils from the manufacture of crude carbolic acid, naphthalene and anthracene. This description, however, applies especially to the creosote oil produced in the best-managed works. In some works, every residue which cannot be used for any other purpose finds its way into the creosote-oil well." In consequence of this uncertainty of composition, most railroads and other large

* Com. Org. Anal., 3d Ed., Vol. II, Part II, p. 294.

users of creosoted timber have had prepared more or less rigid specifications as to what should be the physical and chemical character of a creosote oil to be used for the impregnation of timber.

These specifications had reference to specific gravity, percentage of phenols (or tar acids), of naphthalene allowable, and to the range of temperature within which the oil should distill. Until recently most experts valued the tar acids and naphthalene as the important constituents and demanded definite percentages of each. Now the weight of opinion is in favor of the heavy oils which come over after the naphthalene in the distillation and considers the naphthalene as of no value whatever. This is because naphthalene is volatile at all temperatures and will disappear entirely from the wood in course of time.

As illustrating the views held on the subject of the proper composition of a creosote oil for timber preservation I will quote a few foreign specifications and a few American ones of different dates.

The Belgian State Railways specify for creosote oil, "Specific gravity 1.05 at 15° C., 5 per cent tar acids, one-third distilling at 200°–250° C. and two-thirds at 250° and above."

The Western Railway of France. "Specific gravity minimum 1.015 at 50° C., 6 per cent acid, should be completely liquid at 40°, at 15° a minimum of 10 and a maximum of 25 per cent solid deposit allowed."

Roumanian State Railway. "Specific gravity 1.05 to 1.10 at 15°, 6 to 10 per cent phenol, one-third distilling at 200°–250°, 1 per cent green oil between 288°–400°, completely liquid at 40°, 10 to 30 per cent of naphthalene."

German Impregnating Works. "Specific gravity 1.02 to 1.055 at 15°, 10 per cent to be dissolved in soda solution of 1.15 sp. gr., up to 150° nothing distilling, 150°–235° 25 per cent as a maximum, all should distill between 150°–400° C."

Letheby's English Specifications. "5 per cent acids, 90 per cent should distill below 315° C."

Midland Railway Co. of England. "Specific gravity of 1.04 to 1.065 at 90° F., not less than 25 per cent not distilling at 600° F. (315° C.) and not less than 6 per cent tar acids."

Of these specifications, the Belgian, German and Midland Railway Company show the influence of the more recent views,

while the others practically demand naphthalene and do not insist on the heavier oils as essential. The American specifications are all of relatively recent date, and show in the main the change of views as to what is considered as desirable.

Herman von Schrenk of the U. S. Forestry Bureau in 1903 * proposed the following: "The specific gravity must be about 1.04 to 1.10 at a temperature of 20° C. The boiling point must be as follows: up to 150° C. nothing must come off; up to 200° C. not more than 10 per cent may come off; up to 235° C. not more than 25 per cent may come off; up to 355° C. at least 90 per cent must come off. The oil must be soluble in benzene or in absolute alcohol."

These specifications are relatively high. In 1905 E. H. Bowser † of Louisiana, who had been practically engaged in creosoting work in that state, proposed: "The specific gravity shall be not less than 1.04 at 35° C.; it shall not yield more than 10 per cent by weight when distilled up to 210° C.; between 210° and 235° C. the distillation shall not be less than 25 nor more than 30 per cent and at least 30 per cent by weight shall not distill below 260° C." These specifications were quoted with approval by H. R. Standford in a paper read before the American Society of Civil Engineers, Dec. 20, 1905.

In Circular 141 of the Forest Service, U. S. Department of Agriculture, entitled "Wood Paving in the United States," the specifications of the City of Minneapolis for creosote oil for wooden block impregnation are given. These state: "The specific gravity of the oil at 20° C. shall be at least 1.09; the oil shall be completely liquid at 25° C. and show no deposit on cooling to 22° C.; it shall not contain more than 2 per cent of water, nor more than 3 per cent of matter insoluble in absolute alcohol or benzene; on distillation, up to 150° C. nothing must come off, up to 170° C. 2 per cent, up to 210° C. from 6 to 8 per cent, up to 235° C. from 20 to 30 per cent, up to 315° C. from 40 to 50 per cent, up to 355° C. from 60 to 80 per cent." It will be seen that this calls for a relatively heavy oil, containing high-boiling fractions.

The most recent publication which deals with this subject in detail is Circular 112 of the Forest Service on "The Analysis and Grading of Creosotes," by Dean and Bateman, issued Feb. 26, 1908. The authors have studied a large number of samples of creosote

* Yearbook of the Department of Agriculture for 1903, p. 435.

† Jour. Association of Eng. Societies, April, 1905.

oil from coal tar as well as from other sources, and as a result of their studies propose four grades of creosote oil, designated respectively as Grades A, B, C, and D. They give the distillation curves of each of these, as well as note their accordance with certain limits of specific gravity, index of refraction, and percentage of oil remaining after sulphonation test. The distillation range, as might be expected, is high for the better-grade oils.

The question as to what should be the composition of a creosote oil has been attacked, however, with very satisfactory results by extracting the oil from creosoted timber which has stood exposure for some years and examining it as to its composition. Thus, von Schrenk in 1907 in a paper read before the New England Railroad Club gives as the result of his examination of oil extracted from creosoted timber in service from 1897 to 1906 percentage figures indicating that "during the nine years of exposure, the naphthalene fraction has practically disappeared from the wood above the ground." In that part of the creosoted timber below the ground it had diminished but had not disappeared.

Prof. Gellert Alleman, however, has more recently published a fuller study of this question of the character of the extracted oils. He obtained these oils from railroad ties, piles, and paving blocks, in all 37 samples, which had been creosoted in both English and American practice and had been in service for periods varying from 9 to 47 years.

His conclusions are as follows:

"The creosotes recovered contained practically nothing which boiled below 205° C. The general average shows that 32.9 per cent of the oils distilled below 270° C., and 66.95 per cent above—that is, two-thirds above and one-third below this rather high temperature. Another noticeable fact is the large amount of solid anthracene oil recovered from the distillates of many samples, the highest being 57 per cent.

A distinctive feature of the creosotes from American piles was the quantity of naphthalene which they contained. The average from this class of timbers was nearly 26 per cent, and one sample showed over 48 per cent. It appears probable that the creosotes used in treating these timbers contained much more naphthalene than the oils applied to the English piles. The results indicate that this substance possesses value for timber treatment, although it probably is inferior to anthracene oil.

It is worth noting that these long-lived American piles contained more anthracene oil than naphthalene.

Perhaps the most striking thing is the disappearance of the tar acids. It is certainly conservative to place the original tar acid-content at 5 per cent. Yet the extracted oils showed but a tenth of this amount. . .

It appears, therefore, that light oils, boiling below 205° C., will not remain in timber, but that heavy oils, containing a high percentage of anthracene oil, will remain almost indefinitely and protect the wood from decay and boring animals. It is probable that naphthalene stays in wood for many years, but whether it is as valuable as anthracene oil is open to question. The value of the tar acids has apparently been overestimated by many persons, for although it has not been proved that they are valueless, they have been shown to possess poor staying qualities.

The Circular 112 of the Forest Service on "The Analysis and Grading of Creosotes," by Dean and Bateman, to which reference has already been made, is one of great importance in that it seeks to reduce to more exact definition the characters that should give value to creosoting oils. They say as bearing on this: "The important chemical properties of a creosote which fit it to be a preservative are those which increase its toxic qualities towards fungi and wood-destroying insects. Although there are exceptions, it is a general rule that the compounds belonging to the aromatic series are more poisonous to both plants and animals than those in the paraffin and olefin series, and the former are consequently of much greater antiseptic value. A pure coal-tar creosote will protect properly treated timber for a great many years. What protection will be afforded by the distillates from other kinds of tar is as yet an open question, but the increased production of these tars and the growing practice of distilling them make it imperative that definite information regarding their preservative value should be acquired. At present, despite the apparent approximation to the composition of coal-tar creosotes by the creosotes from oil or water-gas tars, the known preservative value of the pure coal-tar creosotes makes them of greater market value. We must, therefore, regard the creosotes obtained by distillation of properly made coal tars as the highest grades for preservation. . . . In addition to being a pure distillate from coal tar, the

creosote must also possess a composition which gives it properties falling within narrow limits."

In studying selected coal-tar creosotes, they note first the difference in volatility (or percentage of volatile constituents), which, as has been seen, rapidly disappear from the treated wood and therefore have little value. They next note as the distinguishing properties of pure coal-tar creosotes the index of refraction, the specific gravity and the sulphonation test. The meaning of this last test is thus stated by the authors on p. 20 of Circular 112: "If a fraction from the distillation of a creosote oil be treated under proper conditions with concentrated sulphuric acid, it will be converted into a mixture of sulphonic acids, which will readily dissolve in water. If, however, there are paraffin bodies present, they will not be attacked to the same degree as the aromatic hydrocarbons and when the products of the sulphonation are treated with water the paraffin components will remain as residual oil. In applying this test to creosote oils, it has been found that the most information is obtained by using it on the higher boiling fractions."

Messrs. Dean and Bateman have extended their study of creosote to oils made from what they term "oil-tar," but what I would prefer to call "water-gas tar," as designating more specifically the conditions of its formation, as the temperatures used in making carbureted water gas are very different from those used in making what is called "oil-gas" for which so-called "gas-oils" are used. On page 26 they summarize their results as follows: "It will be seen from these data that both the specific gravity and index of refraction is lower in the case of the oil-tar creosotes than in that of the coal-tar creosotes. Moreover the high-boiling fractions of the oil-tar creosotes always yield an oily residue from the sulphonation test. The index of refraction of this residuum is very low, falling in the general range of crude petroleum. This indicates that some of the gas-making oils get through the producer without being decomposed and appear in the tar."

As I had put at my disposal recently a sample of creosote oil distilled from water-gas tar, made at the high temperatures now customary in the manufacture of carbureted water-gas, I have submitted it to the different tests of Dean and Bateman's pamphlet in comparison with a coal-tar creosote of known make. The physical and chemical tests upon the two oils, the distillation

records and tests of different fractions from the distillation are all stated in a series of tables which are here appended.

PHYSICAL AND CHEMICAL CONSTANTS OF WATER-GAS AND COAL TAR CREOSOTE

	I. Water-gas Tar, Creosote Fraction.	II. Coal Tar, Creosote Fraction.
Specific gravity at 60° F	1.07	1.117
Consistency at 60° F	Relatively thin liquid	Thin liquid
Consistency at 32° F	Still thin liquid	"
Index of refraction (at 40° C.)	1.637	1.563
Index of refraction (at 60° C.)	1.6315	.....
Viscosity at 100° C.	55 seconds (Engler)	47 seconds (Engler)
Sulphonation test	2.14%	1.118%
Evaporation per cent 4 hours at 98° C.	10.07%	89.3%
Percentage of phenols	None	14%

DISTILLATION RESULTS WITH WATER-GAS TAR FRACTION. I.

Fraction	Range in Temperature.		Amount in cc.	Percentage over
1	Up to	260° C.	17.5 cc.	= 5.5%
2	260°	310° C.	28 cc.	= 15.2%
3	310°	330° C.	36 cc.	= 27.2%
4	330°	350° C.	95 cc.	= 48.7%
5	350°	370° C.	63 cc.	= 69.8%
6	370°	380° C.	33.5 cc.	= 81.0%
7	Residue	....	57 cc.	= 19.0%
			300 cc.	= 100.0%

	Refractive Index.		Sp. Gr. at 15°	At 60° C.
	At 40°.	At 60°.		
Original	1.6370	1.6315	1.073	1.0448
Fraction 1	.....	.....	0.904	0.8758
" 2	1.5892	1.5800	1.017	0.9888
" 3	1.6181	1.6095	1.054	1.0258
" 4	1.6371	1.6288	1.074	1.0458
" 5	1.6540	1.6450	1.093	1.0648
" 6	1.6525	1.6434	1.086	1.0578

Additional Distillation Results with Water-Gas Fraction. I.

Fifteen hundred cc. of the 1.073 water-gas tar-oil were distilled in an iron retort and 375 cc. collected between 160°–343° C.; 300 cc. of this was fractioned in a Hempel distilling flask (thermometer exposed above 60° C. Temperature of stem 40°–85° C.)

Fractions.	Range of Temperature.		Amount in cc.	Percentage over
1	160°	200° C.	34.5 cc.	= 11.5%
2	200°	240° C.	24.5 cc.	= 19.7%
3	240°	280° C.	52 cc.	= 37%
4	280°	300° C.	54.5 cc.	= 55.2%
5	300°	320° C.	37 cc.	= 67.5%
6	320°	330° C.	27 cc.	= 76.5%
	Residue	....	70.5 cc.	= 23.5%

	Refractive Index.		Sp. Gr. at 60° C.
	At 40°	At 60° C.	
Fraction 1	No film	No film	0.8537
" 2	"	"	0.9124
" 3	1.5718	1.5622	0.9716
" 4	.....	1.5872	1.009
" 5	.....	1.6006	1.029
" 6	.....	1.6165	1.018

Viscosity in Pipette at 180° F.

Barrett Co. creosote oil ..... 25 cc. = 15 seconds
Water-gas tar fraction 1 ..... 25 cc. = 15 seconds

Distillation Results with Coal-Tar Creosote. II.

Fraction.	Range of Temperature		Amount in cc	Percentage over
1	Up to	200° C.	27.6 cc.	= 9.2%
2	200°	210° C.	60 cc.	= 29.2%
3	210°	220° C.	57 cc.	= 48.2%
4	220°	230° C.	44 cc.	= 62.9%
5	230°	240° C.	33 cc.	= 73.9%
6	240°	260° C.	32.5 cc.	= 84.7%
7	260°	280° C.	17.5 cc.	= 90.5%
8	280°	295° C.	10 cc.	= 93.5%
9	Residue in solid		18.4 cc.	= 6.5%
			300 cc.	= 100.0%

	Refractive Index.		Sp. Gr. at 15° C.	At 60° C.
	At 40° C.	At 60° C.		
Original.....	1.5630	.....	1.117	1.084
Fraction 1	1.5340	.....	0.974	0.946
" 2	1.5540	1.5456	1.003	0.975
" 3	1.5665	1.5537	1.021	0.993
" 4	1.5813	1.5710	1.089	1.061
" 5	1.5864	1.5753	1.025	0.997
" 6	1.5929	1.5813	1.028	1.000
" 7	1.5945	1.5854	1.037	1.009
" 8	1.6050	1.5950	1.115	1.084

I am not willing to express a final opinion on these results, but hold them subject to confirmation by additional distillations. The coal-tar creosote oil which I have examined in this connection is also probably fuller of light fractions than some of the coal-tar creosote oils examined by Dean and Bateman. It will be seen, however, that the specific gravities of the fractions from the water-gas tar are not appreciably lower than those obtained from the coal-tar creosote fractions, the indices of refraction are notably higher instead of lower, as found by Dean and Bateman, and the sulphonation test shows a residue which, while larger than that of the coal-tar creosote, amounts to only 2.14 per cent. On the other hand, the evaporation test, the freedom from phenols and the abundance of high-boiling fractions are all in favor of the water-tar creosote. The sulphonation test shows that these high-boiling fractions are not paraffins, and every indication shows that they are most probably just what are indicated by Alleman, von Schrenk and others as the most desirable constituents of a creosote oil, viz., the so-called anthracene oils. Moreover the absence of phenols from this water-gas tar creosote shows that it is a product of high-temperature distillation in which the paraffins have been converted into the high-boiling aromatic hydrocarbons. The identification of these higher aromatic hydrocarbons has been partially carried out and confirm this view.

I would therefore express the opinion that we may possess in this grade of water-gas tar creosote an oil quite specially adapted to wood preservation.

Discussion

S. F. Peckham:

I was listening to President Sadtler's paper with great interest. I have been rubbing up against that subject for fifty years. The first chemical, technological establishment that I ever visited, when I was a student, was engaged in the manufacture of the various commercial products obtained from coal tar. About twenty-five years ago I spent several months, during a visit to the Pacific coast, in testing an apparatus for saturating wood and other fibers with the products of the distillation of coal tar and creosote oil. Creosote oil was then a well-defined commercial article. When anyone spoke of creosote oil he recognized that it was what was otherwise known as "dead oil," obtained in the distillation of coal tar, and rich in phenols, naphthalene and anthracene, and various oils but little known and not named altogether satisfactorily, which held these materials in solution.

It was generally understood at that time that the effects produced by creosote in wood were produced by all of the materials which were added in with the creosote oil. Some people thought that the effect was probably produced by the phenols, others by the naphthalene, others by the oils, and so on. Within a comparatively few years, as it appears to me, the manufacturers of water gas found on their hands a very large bulk—in the aggregate—of so-called water-gas tar, which was as variable in composition as possible. I should judge that the variety of its ingredients was about equal to the number of those establishments that were making the water-gas tar from anthracite coal and various other hydrocarbon mixtures. It was found necessary to find a market for this material. Some of it was distilled, and the distillate was called creosote oil, and the residue was called asphalt. This creosote oil was sold to take the place of the well-known article. It does not appear to me from all that I know concerning the matter, and I know a great deal, that any particular pains were taken to find out by direct experiment, whether one or two or all of these varieties of high distillates, were the proper substitute for creosote oil or not. The problem was to find a market.

Now I am not referring in my remarks to Dr. Sadtler, or his book, or anything that he has said. I am simply stating the case

as it appears to me. Within a decade the use of creosote oil obtained from various sources has had an enormous increase, owing to the demand for it for the impregnation of blocks of wood for use for paving purposes. Now, without wishing to be considered as making fun of anything, I will say that I have heard these arguments advanced, and it appears to me that if a man should find an old shoe with nothing but the insole left, and declare that the insole was the principal constituent of the shoe, his argument would be parallel to the arguments of those who claim that it is proper to use heavy oils to impregnate wood. Heavy oils are found in wood after the lapse of ten, twenty or twenty-five years. They were not carried there as heavy oils. They were carried there in solution in light oils, and are left there as a residuum, just as the rest of the shoe has worn out and left the insole. That those heavy constituents are the proper ingredients, and the proper materials, to be used in impregnating wood, I consider a great piece of folly, and there has not yet been advanced in all the arguments one single word of proof that these heavy oils in being used have ever been forced into the wood as heavy oils. What experience I have had with reference to impregnating wood with various materials proves absolutely, to my mind, that it is necessary to have a very fluid substance in order to impregnate the wood.

The blocks that have been used in recent years in New York city have been analyzed. But a small percentage have proved to be impregnated, and long-continued experiment has shown comparatively few of the blocks to be completely impregnated. I have examined blocks that had a core one-third the size of the block in the interior that was filled with water. A large number of these blocks were laid in one of the streets, and we will hear from them one of these days. Others were not impregnated at all, but simply smeared on the outside with tarry material, and one-eighth to one-sixteenth of an inch from the surface there was nothing introduced. Many square yards—I do not know but many square acres—of such blocks have been laid in New York city in the last ten years. They were all impregnated with so-called creosote oil. Nobody knows where it came from; nobody knows its composition. In one instance I very carefully extracted a number of these blocks, and in examining the residue I could not find that there was in any of them more than the barest trace of naphthalene, and I did

not get any test at all for anthracene; I did not get any test at all for phenols. This material appeared to be petroleum residue—a liquid petroleum residuum. I sent out of the city, through a friend, to a large manufacturer of water gas, and obtained a sample of water-gas tar. On distilling that material I got the same results that I did from the residue from the blocks. There was no evidence that there was anything in it that responded to the ordinary tests which we apply to creosote oil to distinguish it from any other liquid that is black and sticky.

Now I think that the American Institute of Chemical Engineers ought to take this stand: To foster and promote, as far as possible, the calling of things by their right names. I have no quarrel with anybody who wants to impregnate blocks of wood with water-gas tar, or with any tar, if he can prove that it is an efficient material for both mechanically and chemically preserving the wood. But why not call it a distillate of water-gas tar and sell it as such? Why call it creosote oil when it is not creosote oil? Why call a material asphalt that is nothing in the world but a residual petroleum made under conditions that make it impossible that it should be fitted for paving purposes? Why call it asphalt and put it down as a paving surface, to wear out in two or three years and be worse than nothing, as has been done over and over again?

J. C. Olsen:

I happen to be familiar with the experience of a railroad company in the West on this matter of wood preserving, and I think that Mr. Peckham has omitted to give us certain facts—at least it seems to me that he has created a rather wrong impression. The railroad company experimented with two preservatives, zinc chloride and creosote, or at least one of the numerous tarry materials that have been mentioned. Zinc chloride was found to be an excellent preservative, but being soluble was washed out with water. When they used oil, they experienced the difficulty mentioned, that it was impossible to get it to penetrate the wood. I think it is impossible to take a paving block or tie, or any other piece of wood, and get this oil to go clear through. The solution of the problem seemed to be very simple. Put the two together; the zinc chloride had the penetrating power, and would go into the heart of the wood, while the oil, of course, would penetrate only the exterior and would preserve that. Further, this tar

would act as a water-proofing material and keep the zinc chloride from dissolving out. So that, in their practice, it did not make any difference whether the material contained the real creosote—the phenols which prevent decomposition. It seems to me that the experiments on this wood which has been in the earth so long must be along the same lines. The tar—that is the creosote oil—originally used contained a material which would penetrate the wood, and which probably had preserved it. This in time volatilized, while the heavy material remained. The heavy material may have kept the lighter in for a long time, and thus have assisted in its wood-preserving function. It seems to me that the action of the creosote oil is complex; we cannot ascribe its properties to any one constituent. The heavy material certainly would remain on the surface, and prevent the penetration of moisture and oxygen, while the phenols would prevent decomposition by bacteria. This combination with chloride of zinc seems to me to be an excellent preservative.

H. O. Chute:

In connection with the preservation of wood with creosote oil, nothing has been said about the preservative properties of wood tar. Last summer I tried to investigate that subject somewhat because I was up in Cleveland, Mich., where there are large creosote works. It was within sight of a factory that was making a very large quantity of wood tar. The factory was burning up all the wood tar. I was informed that there are about 16,000,000 gallons of wood tar produced in the United States. Probably two-thirds of that will boil over within about the limits of what we call creosote oil, and this brings up the question as to whether it really is creosote, and I think it probable that the preservative qualities of wood tar give it a right to the name. It is well known, of course, that it is antiseptic, as ourselves and our ancestors have preserved our meat with it, and all the cordage that was formerly made and largely used in the naval industry was preserved by wood creosote. Whether it has ever been thoroughly tried out on wood or not I have been unable to learn. The Forestry Bureau has done enormous work on wood preservation, but they seem to have passed over this source of what may possibly be a preservative. While we are importing large quantities of preservatives from England, Europe and foreign countries, we are wasting a large quantity of

wood tar. Whether it is valuable as a timber preservative or not I am unable to say. If anyone has any information on the subject, I shall be glad to receive it.

Pres. SADTLER:

I would like to say a word on one or two of the points that the gentlemen have made.

Wood tar hardly comes into competition with coal-tar creosote. Wood tar is a low-temperature distillation product and contains pyroligneous acid. These acid products render it unsuitable for the preservation of wood, and at the same time are of themselves a source of revenue. In addition to this, the particular creosote fraction in wood-tar is entirely too expensive. It has a value for medicinal purposes. The price of wood-tar creosote, so far as I know, is very distinctly beyond that obtained for the common creosote fraction, used for the preservation of railroad ties or that kind of work. Wood-tar creosote is in a class by itself and is of great value for certain specific purposes; it is not a waste product.

With regard to some of the points which Prof. Peckham raised I would say this: Of course it is not for a moment thought that merely the heavy oils alone would be desired that would not go into the wood, and would only stay on the exterior—and so on. The first qualification is that the oil shall be sufficiently thin at different temperatures so as to have penetrating power at those temperatures. If it goes in, then the light portions can be lost afterwards without any particular harm. Of course those heavy residual fractions will do the work. The history of this matter is simply this: For a long while the work was carried on by small private companies doing custom work for the railroads, as, for instance, the firm referred to by Dr. Olsen, Allardice & Co. Work of this kind has been practically given up at the present time. The chief work has been done along the Gulf, in Louisiana, Mississippi and Texas, by two or three of the large railroads—the Southern Pacific for example. They have given up using everything but oils. They require a preservative for wood that is not only to be exposed to the atmosphere, but which is to be submerged in water. There is absolutely nothing that will enable the timber to withstand the ship worm except creosote. The Forestry Bureau's work in the last few years has been much more thorough than that done by private companies. A large number of papers

have been published by the men in the service of the bureau, first by Dr. von Schrenk and later by Prof. Alleman, who is still connected with the Forestry Bureau. Coming down to this point, the main requirements are that you should have oils which are thoroughly antiseptic, thin enough to go into the wood, and of such high boiling character so as not to evaporate readily. Naphthalene has been given up on all later specifications. Naphthalene will go out in woods that are exposed—sleepers, telegraph poles, etc. The tar acids disappear practically entirely and have been given up. The thin oils which go along with the naphthalene and the anthracene oil are now regarded as the most desirable things. They should have distinct antiseptic qualities. Petroleum residuums have not that antiseptic quality. Doubt has been expressed as to whether they are carried in water-gas tar. The petroleum compounds used in carbureting are never perfectly converted. If the temperature of distillation is low they cannot be converted. As water gas is manufactured now very high temperatures are employed, and I am inclined to think that the petroleum hydrocarbons are almost completely destructively distilled. If you check up by proper tests I think you can guard against being deceived by petroleum residuum. If you can get rid of these and have simply then the aromatic hydrocarbons and higher phenolic fractions, but higher than ordinary phenol and creosol, I think you will have a very good material. The specifications of the city of Minneapolis are all in that line now. The specifications of the Department of Forestry are also in that line. My whole study was simply to see whether the so-called high temperature water-gas tar would fill the requirements. I am inclined to think it will, and if so it will become a wide source of supply, since the domestic supply of true coal-tar creosote is limited, and a great deal has to be imported.

I have not yet finished the study of this subject, and would not like to pass a final opinion until I have done a little more.

S. F. Peckham:

There is a point I omitted. It is necessary in order to saturate any material containing microscopic fibers or pores, that the material used shall be extremely fluid. The old-fashioned creosote oil, so called, is a material extremely susceptible to changes of temperature. It becomes as fluid as water and is very penetrating.

It will penetrate microscopic cells where a more dense material will not enter at all. The material that I have received and examined as water-gas tar yields no fluids that are as susceptible to changes of temperature as the straight creosote oil. That is a very important matter. Wood blocks on streets that are simply smeared with something that is black and sticky, that are put down filled with water, or empty of anything, are going to be an extremely expensive job for those that make them.

Pres. Sadtler:

I should like to say with regard to that, that much more than the mere chemistry of the matter comes into the method of treatment. In the old method of treatment the wood was placed in closed cylinders and first of all heated so as to thoroughly displace all moisture before putting in the tar. The wood was never so effectively treated as in the more modern process which the Forestry Bureau has introduced. The process is carried out in an open tank. The wood is put into the creosote oil, which is then heated by closed steam coils to a high temperature—considerably above that at which steam would be driven out—for a considerable period. The timber is thoroughly swollen, the moisture goes out, and the air is largely expelled, while it is completely immersed in hot creosote oil. Then the wood is quickly taken out of that hot tar, and immersed with as little exposure to air as possible into cold creosote oil, and allowed to cool down to ordinary temperatures, and kept there for a few hours, until by contraction of the cellular tissue the cold creosote oil is taken into the interior to a very notable degree. The Forestry Service claims for this that it is much more effective than the closed-cylinder treatment. Now, after treatment like that, it cannot be a question of a mere scum covering the surface of the wood. If the process is carried out properly the blocks are going to be saturated far more thoroughly than has heretofore been done.

H. O. Chute:

With regard to wood-tar creosote, I appreciate Dr. Sadtler's remarks about wood tar being a product which would give on distillation pyroligneous acid. That is true of the wood tar that was produced formerly. Nowadays that tar is distilled and the pyroligneous or acetic acid is entirely driven out. The wood tar

that I referred to is the residuum from that. Of course, incidental to driving out the acetic acid, a large quantity of low-boiling oils are driven out, but the residuum contains a large quantity of oils which will boil at about the same temperature as the coal-tar creosote. A considerable quantity of the distillate will dissolve in alkalis. While it is true that you can buy in the drug store wood creosote at a dollar a pound, it is still a fact that out of 16,000,000 gallons of wood tar produced in the United States, at least 15,000,000 gallons are now burned under boilers, and a few years ago in the natural-gas region it was simply run into the streams. This has been prohibited by the state sanitary authorities, and consequently the manufacturers have been compelled to burn the tar. At the present time there is no market value for this tar higher than their value for fuel.

Pres. Sadtler:

I would be very glad to see a sample of the tar referred to. I do not know much about its qualities.

H. O. Chute:

It is not, as I said, a merchantable article, and I know of but one factory in the United States that has made attempts to manufacture any products of hard-wood tar. Of course pine-tar is an article of commerce, and is useful, but what I refer to is that made from the destructive distillation of hard wood (beech and maple) as conducted in the North, not in the South, where pine tar is produced for commercial purposes.

SOME EXPERIMENTS ON THE CASE HARDENING OF STEEL BY GASES*

By JOHN C. OLSEN, JOHN S. WEIFFENBACK and JOHN R. BRIERLY

Read at the Brooklyn Meeting, June, 1909

As is well known, for many purposes it is found convenient to use steel having a soft core and a very hard outer layer or case, the hardness of the material being dependent upon the presence of carbon in greater or less amount which is held in solution as the result of a process of annealing. If the steel contains a small amount of carbon in the core and a larger amount in the outer layer the process of annealing will produce a hard case and leave the core soft and tough. The older methods of case hardening consisted of heating the iron in contact with a great variety of solid material invariably containing carbon in large amount and in smaller amount, nitrogen, and at times alkaline substances. Charred organic material was usually used such as wood charcoal or burnt leather; the latter being advantageous because of its high nitrogen content. Such charred organic matter is invariably alkaline from the decomposition of the alkaline salts originally present in the vegetable fibers. Potassium cyanide has also been used. This salt contains the alkali, carbon, and nitrogen. As a result of heating iron in contact with material of this kind the iron absorbed more or less carbon, the amount depending upon the temperature to which the mixture was heated, the materials present, and the length of time of the heating. Investigation has shown that the absorption of carbon is much more rapid from material containing nitrogen and further that this nitrogen must be in combination, free nitrogen having no influence on the process. After the proper amount of carbon had been absorbed the sample was tempered by heating to the proper temperature and plunging into cold water or oil.

* The authors are under obligation to the American Gas Furnace Co. for the use of one of their furnaces for this investigation.

Recently the use of gases instead of the solid carbonaceous material has been introduced, and processes of this kind are used commercially to-day. We can find no published record of experiments conducted to ascertain the relative efficiencies of the various carbon gases. This investigation was undertaken to study this question and also to ascertain what chemical reactions take place when the carbon from a given gas enters the steel. The temperature at which the case hardening must be carried out has been pretty closely determined by previous workers, i.e., from about 700 to 900° C., or 1300 to 1700° F. It has also been ascertained that if the case hardening is carried out with gases subjected to a certain amount of pressure the action is much more rapid. This was to be expected, inasmuch as the carbonaceous material is in this manner concentrated in the vicinity of the surface of the steel, that being the only place where action can take place.

We have used in our experiments the following gases: illuminating gas, as supplied in Brooklyn by the gas companies; methane, carbon monoxide, and acetylene. The illuminating gas of Brooklyn contains on the average about 26 per cent of carbon monoxide, the same per cent of hydrogen and methane, about 12 per cent of "illuminants" consisting of ethylene, acetylene, and benzene and smaller proportions of free nitrogen, oxygen, carbon dioxide, etc. The acetylene was that used in automobiles for lighting purposes. As 98.5 per cent of the gas was absorbed by bromine it was considered sufficiently pure. The other gases were made in the laboratory and were very nearly pure. The carbon monoxide was made by decomposing oxalic acid with sulphuric acid and absorbing the carbon dioxide by means of strong caustic potash solution. The methane was made by heating a mixture of sodium acetate and soda lime in a copper retort.

Experiments were carried out with each gas alone and mixed with a definite amount of ammonia gas. The ammonia gas was mixed with the carbon gas by bubbling the latter through Wolff bottles containing an aqueous ammonia of definite strength. The amount of ammonia introduced into the gas was ascertained by allowing a liter to pass through a definite amount of standard sulphuric and titrating back the excess of acid with standard alkali. The per cent of ammonia gas was then calculated.

Three strengths of ammonia were used, as follows:

(*a*) 125 cc. of 28.5 per cent ammonia with 875 cc. of water.

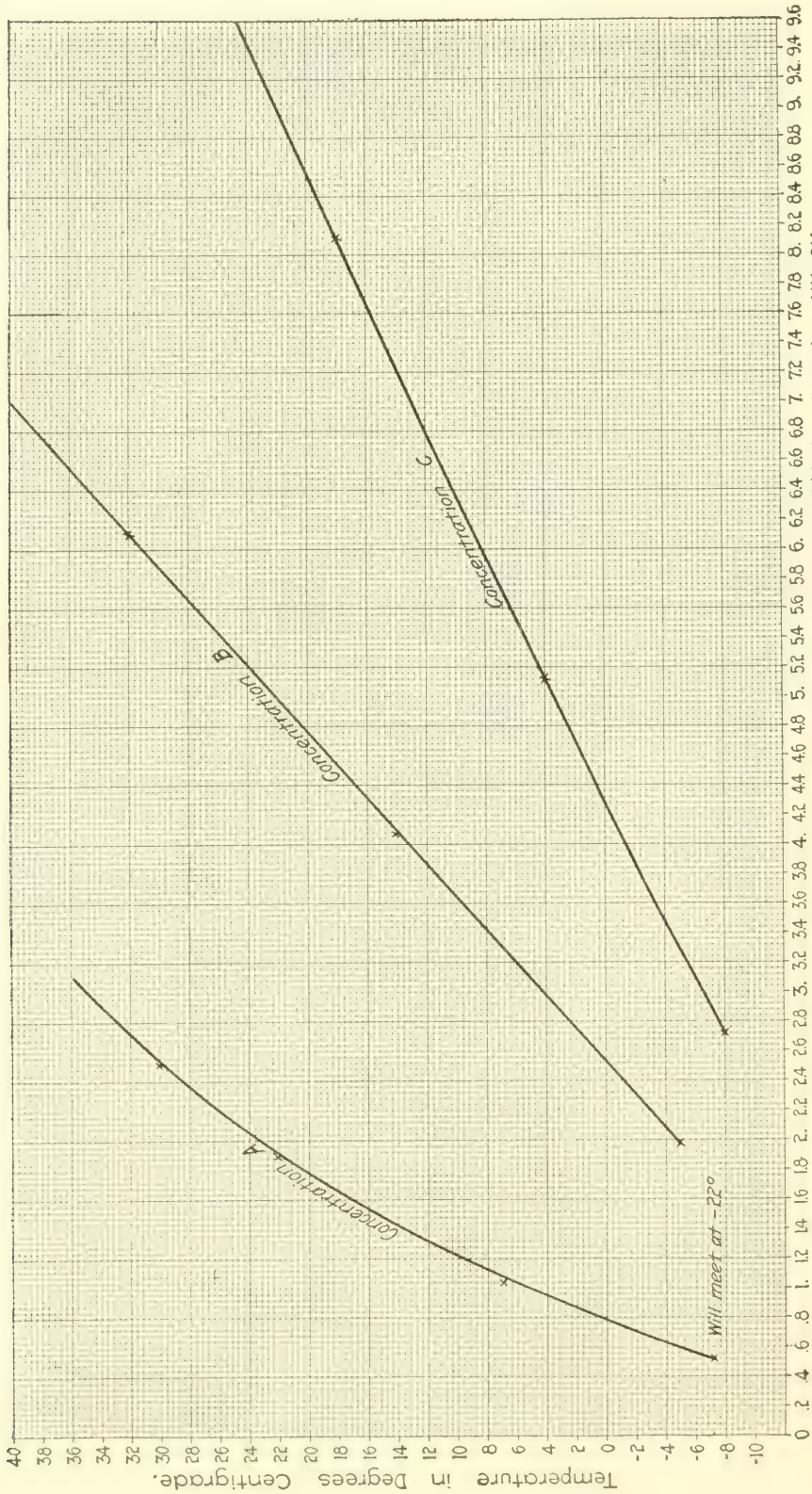


FIG. 1.—Curves showing the relation between temperature and the percentage NH_3 carried when illuminating gas is bubbled through NH_4OH.

Concentration A = 125 c.c. NH_4OH (Sp. gr. 902) + 875 c.c. H_2O (distilled)
" B = 250 c.c. " " + 750 c.c. " "
" C = 500 c.c. " " + 500 c.c. " "

(*b*) 250 cc. of the strong ammonia with 750 cc. of water, giving (*b*) double the strength of (*a*).

(*c*) 500 cc. of strong ammonia and 500 cc. of water, giving ammonia twice the strength of (*b*) and four times the strength of (*a*).

The illuminating gas was bubbled through the ammonia at different temperatures, the Wolff bottles being placed (1) in an

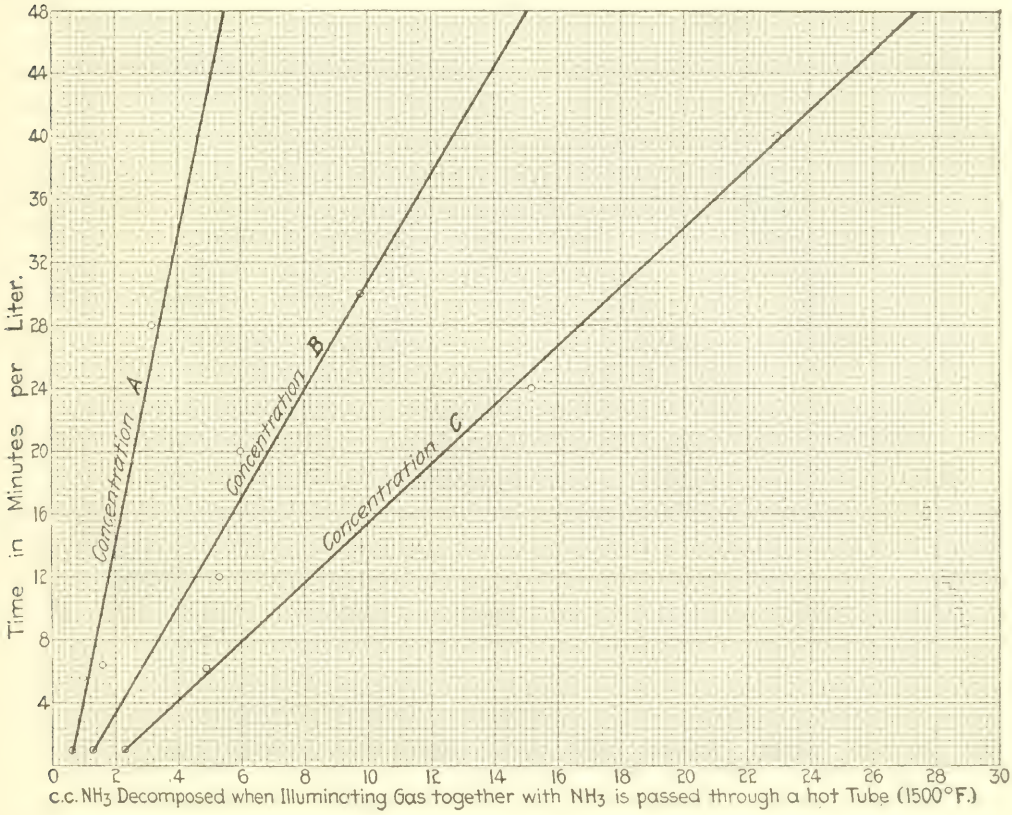


FIG. 2.—Curves showing relative amounts of NH_3 decomposed when illuminating gas is bubbled through different concentrations of NH_4OH and then passed through a tube (heated to 1500° F), at different speeds.

Concentration A = 125 c.c. NH_4OH (Sp. gr. 902) + 875 c.c. H_2O
" B = 250 c.c. " " + 750 c.c. "
" C = 500 c.c. " " + 500 c.c. "

ice-and-salt mixture, (2) in ice-water, (3) in water at room temperature, and (4) in water heated considerably above room temperature. The curves shown in Fig. 1 were then plotted. These show that the amount of ammonia gas carried through is a function of the temperature and also of the concentration of the ammonium hydroxide.

Experiments were first carried out with the illuminating gas, to ascertain if the ammonia would combine with the carbon monoxide or other carbon gas present to form cyanides or cyanogen, it being thought that the following reaction might take place:

$$CO + NH_3 = H_2O + HCN.$$

For this purpose the mixture of ammonia and illuminating gas was passed through a glass tube which was heated in a combustion furnace to the case hardening temperature, 800° C., or 1500° F. The temperature was measured by means of Seger cones and pieces of potassium and sodium chloride. The sodium chloride melts at 804° C. The potassium chloride melts at 772° C. Seger cone No. 17 was used.

The mixed gas after passing through this tube was allowed to bubble through caustic soda solution and cyanides were tested for by the well-known and very delicate Prussian blue test, ferric and ferrous iron being added and the solution then acidified with hydrochloric acid. No test whatever for cyanides was obtained. It was thought that cyanides might be formed in the combustion tube and then decomposed so that no test would be obtained in the caustic soda solution. Another experiment was therefore made to ascertain if hydrocyanic acid could exist at the temperature of the glass tube. For this purpose a flask containing a small amount of potassium cyanide and a little sulphuric acid was introduced so that the gas bubbled through this flask before entering the heated glass tube. A test made for cyanides on this gas on leaving the hot glass tube gave a very excellent test for cyanides. It was concluded, therefore, that the ammonia did not react with the constituents of illuminating gas to produce cyanides. We have not ascertained how ammonia assists in the case hardening process.

We next conducted an experiment to ascertain what portion, if any, of the ammonia was decomposed when the mixed gases were heated to the annealing temperature.

For this purpose the illuminating gas mixed with ammonia from solution (*a*), (*b*), and (*c*) was passed through the hot glass tube at different speeds. A set of curves was plotted to show the results of this experiment. These curves, Fig. 2, show that the amount of decomposition depends upon the speed at which the

gas is passed through the hot tube, the greater decomposition taking place when the lowest speed is used.

It will be observed that the proportion of ammonia decomposed is not constant, but increases rapidly with the concentration of the ammonia, so that while in (*c*) we started with five times as much as (*a*) after heating only about $3\frac{1}{2}$ times as much as was present.

SUMMARY OF EXPERIMENTS V TO XVII

Experiment.	Gas Used.	Time. Hours.	Hardness.	Depth of Case.	Carbon Composition.
V.	Illum. NH_4OH (*a*)	4	glass	0.1 mm.	0.57 %
VI.	Illum. NH_4OH (*b*)	4	glass	2/30 mm.	0.665%
VII.	Illum. NH_4OH (*c*)	4	glass	2/30 mm.	0.915%
VIII.	Illum.	4	none	none	none
IX.	Illum. NH_4OH (*a*)	8	glass	3/10 mm.	1.12 %
X.	Illum. NH_4OH (*b*)	8	glass	3/10 mm.	1.16 %
XI.	Illum. NH_4OH (*c*)	8	glass	3/10 mm.	1.15 %
XII.	CO NH_4OH (*c*)	4	glass	4/10 mm.	1.45 %
XIII.	CO	4	glass	4/10 mm.	1.36 %
XIV.	CH_4NH_4OH (*c*)	4	little	not well defined	0.32 %
XV.	CH_4	4	little	not well defined	0.26 %
XVI.	C_2H_2 NH_4OH (*c*)	4	glass	3/10 mm.	0.98 %
XVII.	C_2H_2	4	little	not well defined	0.41%

The actual case hardening experiments were carried out on samples of soft Norwegian iron containing only 0.08 per cent of carbon. This iron was purchased in rods 1 cm. in diameter which were cut up into 6-inch lengths. A common gas pipe was used for the case hardening. It was heated in an ordinary combustion furnace, the temperature of 1500° F. being maintained throughout the experiment. The per cent of carbon in the iron both before and after case hardening was determined by dissolving the iron in cupric potassium chloride, oxidizing the undissolved carbon by means of chromic anhydride and sulphuric acid, absorbing the resulting carbon dioxide in caustic potash and weighing. The samples for analysis were obtained by turning off the outer layer of metal on the rod in a lathe. On many of the samples this was impossible on the annealed and hardened sample, but on drawing the temper it was found a simple matter to obtain samples.

The depth to which the carbon penetrated was obtained by breaking the rod and measuring the hard case by means of a microscope fitted with an ocular micrometer.

It is evident that ammonia gas facilitates the case hardening in all cases except that of carbon monoxide, which seems to act almost as well without as with ammonia. Of the three gases studied the carbonizing ability is in the following order: Carbon monoxide, acetylene, methane. Carbon monoxide, therefore, is, by far the best gas for this purpose, as no ammonia seems necessary and it gives the best penetration in the same time.

A few experiments were carried out to ascertain the chemical reactions taking place during the carbonizing. In the case of carbon monoxide the gas was freed from carbon dioxide by bubbling through strong caustic potash solution before entering the case hardening tube. On emerging from this tube a considerable amount of carbon dioxide was found present. The carbon monoxide must therefore break up according to the following reaction:

$$2CO = C + CO_2.$$

With methane the reaction takes place according to the following equation:

$$CH_4 = C + 2H_2.$$

This was ascertained by analyzing the gas emerging from the case hardening tube by mixing with air and passing over palladium sponge, 9.45 per cent of hydrogen being found.

The acetylene gas apparently breaks up during carbonization, according to two reactions:

$$2C_2H_2 = CH_4 + 3C$$

and

$$C_2H_2 = C_2 + H_2.$$

This was shown by the fact that the gas after carbonization contained no acetylene at all, but contained a large amount of hydrogen and also methane. A large deposit of carbon was also found in the tube.

AN AUTOMATIC ACID EGG

By RICHARD K. MEADE

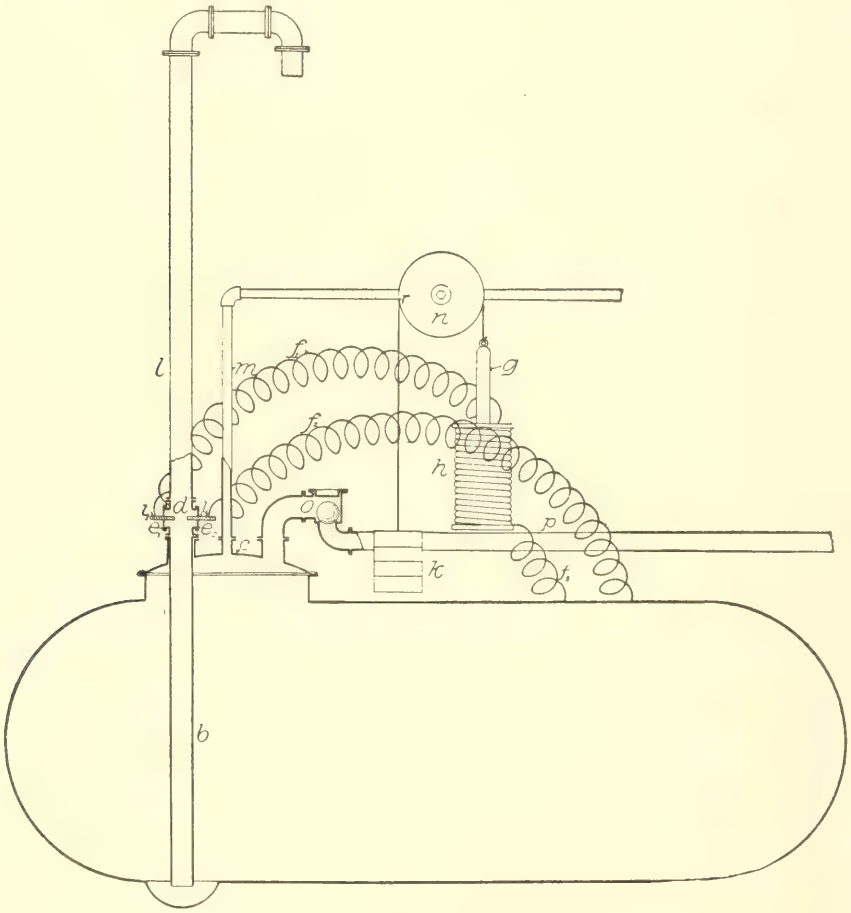
Read at Brooklyn Meeting, June 8, 1909

The elevation of acids is one of the most difficult problems which the chemical engineer has to solve. What has probably proved to be the most satisfactory method of doing this has been by means of the ordinary cast-iron acid egg. The great objection to this apparatus is the constant attention which it requires. On the other hand, it does not get out of order and may always be relied upon to do the work. A number of automatic eggs have been placed upon the market. All of these depend upon a valve operated by a float. The difficulty with these automatic eggs has nearly always lain in the fact that they got out of order easily and that the float occasionally fails to operate the valve.

The following device has been used by the writer to lift sulphuric acid and consists merely of a simple electrical attachment, which may be placed upon the ordinary cast-iron egg, and which is designed to operate the valves, thus doing away with an attendant and so making the egg automatic in its action. It is shown in the accompanying illustration; *a* is the egg itself, *c* is the cast-iron cover which is bolted to this. The acid enters by means of the pipe *p* and leaves by means of the pipe *b*. Air is conducted in by means of the pipe *m*. To the pipe *b* is bolted an ordinary cast-iron cross *d* and to the side openings of this are fastened two porcelain plates, e_1 and e_2. Into these pipes are cemented two ordinary electric light carbons i_1 and i_2, and connected respectively by wires f_1 and f_2 with the electro-magnet *h*, and with the source of current. The other wire f_3 of the magnet is connected with the source of current.

The working of the egg is as follows: The acid flows into the latter throught the pipe *p* and ball valve *o* until the egg is full and it rises to a point above the carbon pencils i_1 and i_2. As soon as

it does this, electrical connection is established and the electromagnet pulls down a bar or core *g* of soft iron. This latter opens a valve *n* and allows the air to enter the egg. The check valve *o* closes, of course, as soon as air enters the egg and causes back pressure in the pipe *p*. The acid is also forced up the pipe *b*. As long as any acid is passing through this pipe the electrical current is, of course, passed through the magnet and the valve



An Automatic Acid Egg.

m is held open. As soon as the current stops the connection is broken and the valve is closed by means of the weight *k*. The valve *n* is made by simply taking off the wheel from an ordinary globe valve and replacing it by a wooden disk with a groove in the edge in which the cord works. The cord is fastened to the disk at one point only, *r*. In place of the magnet, the connection may be made to start a motor-driven air compressor. The elec-

trical current used for operating the egg may be either from the electric light current or from batteries, and the magnet may be located at any convenient point where its workings may be observed. A counter may also be attached to the valve, and if the volume of the egg is known, the liquid so measured.

A METHOD OF CLAY CONTROL FOR THE MANUFACTURE OF CEMENT *

J. G. DEAN

Read at the Brooklyn Meeting, June 24, 1909

Not long ago the writer had charge of manufacturing at a certain cement mill, where the clay used in manufacturing was low in silica and high in iron oxide and alumina. The silica-alumina ratio, $\frac{\text{per cent } SiO_2}{\text{per cent } Al_2O_3 + \text{per cent } Fe_2O_3}$, would average a trifle less than 2.

When pure limestone was used with this clay it was nearly impossible to produce a cement that could be depended on for setting time and tensile strength, and if the lime-content of the mix was high enough to burn properly in the kilns the cement would seldom pass the "boiling test."

In order to overcome this defect in the clay it was necessary to mix the limestone from the upper strata of the deposit, which was siliceous in itself, and carried in addition the sand and silt that filtered into it, with the purer stone from the bottom of the quarry. By this haphazard method we were able to keep the silica alumina ratio high enough to produce a high-grade cement.

This method required very careful mixing and grinding, as with cements having a low silica-alumina ratio the limits of variation are extremely narrow. If the lime-content is lowered the cement becomes erratic in its setting qualities and other peculiarities of over-clayed cement. If the lime-content is raised the cement will fail on constancy of volume tests and will require "air slaking."

These peculiarities become very complicated with such materials when they have been properly proportioned but improperly ground before burning. The mix on analysis will show it to be of the proper chemical composition. The burner will complain of its being "soft" or over-clayed. The boiling test on the cement will

* This method is practiced by the Western Canada Cement and Coal Co., Limited.

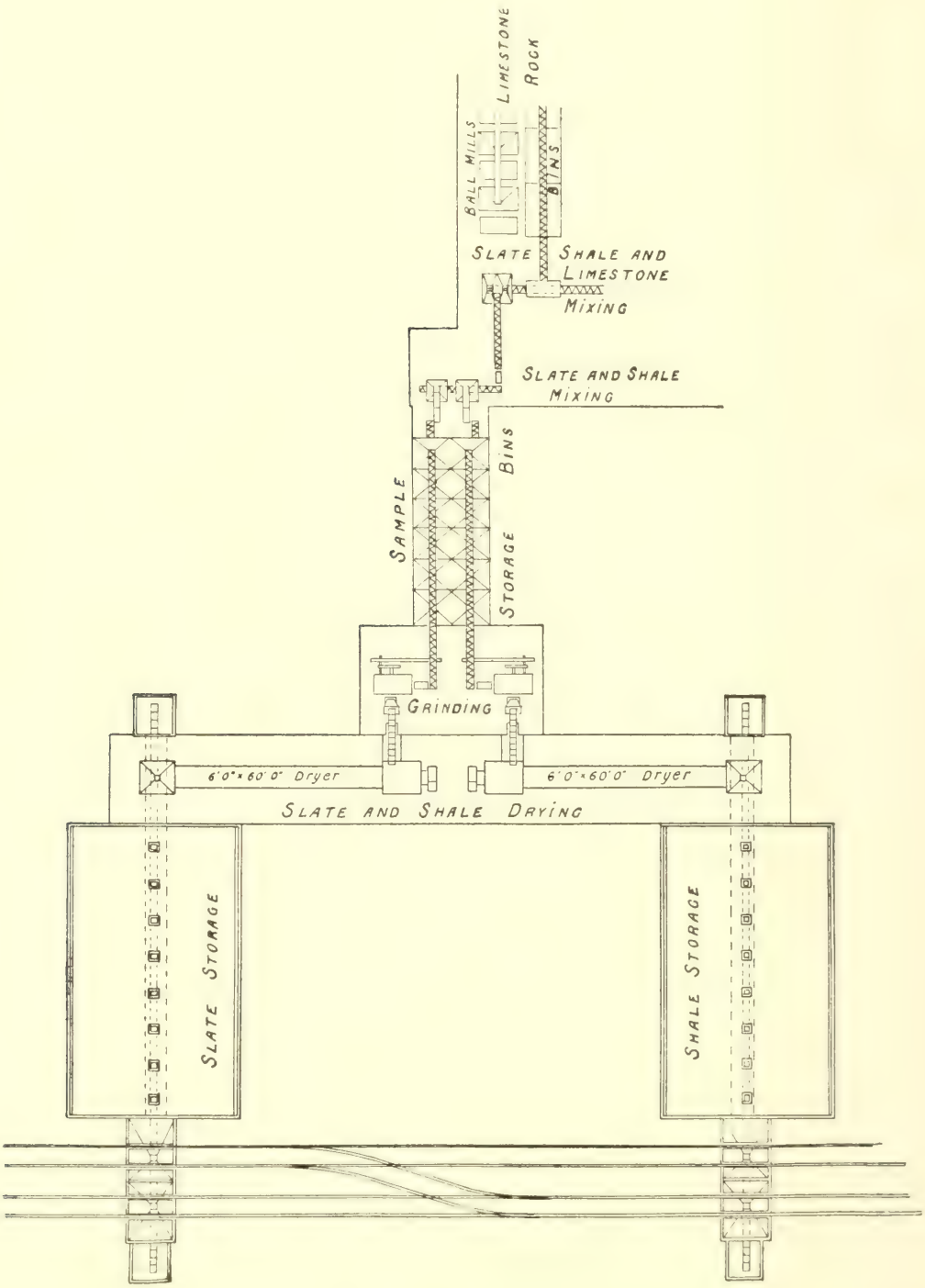
reveal "free lime" and the tests for setting time and tensile strength will indicate an excess of clay, while the chemical analysis of cement will reveal nothing out of the ordinary. This would be a very confusing proposition to solve if it were not for the sieve test made on the mix previous to burning. This will show that that portion of the mix which was capable of combination was over-clayed, and the coarse particles of limestone in the mix were burned to "quick lime," consequently the resulting cement displayed the double characteristics of being over-clayed and over-limed.

One method suggested to improve the silica-alumina ratio of this cement was to add the required amount of fine sand to each mix. With this sand to add a small percentage of fluor-spar to aid in converting the sand so as to eliminate the extra grinding that would be necessary. These two materials were close at hand and could be easily procured, but, as usually is the case, it is a hard proposition to convince those in authority that any improvements can be made in an article that has already made a reputation for quality.

In selecting the raw materials for the present company we were more fortunate as far as clay is concerned. We could not find any one clay material that would answer our purpose, so had to resort to a method of mixing to produce a material of the proper composition.

These two materials happen to be a shale and a slate. The shale has a silica-alumina ratio of 3.00–3.80 and the silica-alumina ratio for the slate 1.50–1.90, so that by mixing these two materials a clay can be produced having any silica-alumina ratio within the limits established by the materials themselves.

Both of these materials are found not far distant from the limestone deposit where the mill is located, and are hauled to the mill in dump-bottom cars by the Canadian Pacific Railway. The slate is dumped from the cars into track hoppers, is fed from the hoppers to a jaw-crusher, from which it is carried to the storage and dryer bin by a McCaslin overlapping bucket conveyor. This conveyor runs beneath the tracks and storage room in a tunnel up over the dryer bin and the storage room in a dormer, across the tracks on a covered trestle and down to the tunnel through a tower. By placing hoppers in the storage floor that pierces the tunnel arch, it is possible to use this conveyor for conveying the slate from the cars to the dryer bin and storage room or from the storage


Limestone Rock
Ball Mills
Bins
Slate
Shale and Limestone Mixing
Slate and Shale Mixing
Sample Storage Bins
Grinding
6'0"×60'0" Dryer
6'0"×60'0" Dryer
Slate and Shale Drying
Slate Storage
Shale Storage

room to the dryer bin. It is also used to convey coal to the dryer furnace.

The slate is fed from the dryer bin to a 60×6 foot dryer by a Gate's rock feeder. This dryer is inclined $\frac{3}{4}$ inch to 1 foot, and has the distinction of having the furnace at the upper end. The draft is regulated by an electrically driven fan at the discharge end. This method of firing has proven itself inefficient and very expensive. This calls for a water-jacketed feeding spout, which is a source of considerable trouble. From the dryer the slate is elevated by a belt elevator to a No. 8 Krupp ball mill provided with No. 25 mesh screens. The crushed slate drops into an elevator boot and is elevated to a screw conveyor above the sample bins, where suitable slides are provided for dumping into the bins.

The shale is handled precisely in the same manner, excepting that it requires no crushing. There are six sample bins side by side for both materials, and as the bins are being filled a sample is taken from the conveyor automatically. When a bin is full this sample is quartered and analyzed.

In these analyses we do not separate the iron oxide and alumina as we have found by our analysis that the ratio of the alumina to the iron oxide in both raw materials is practically constant.

After the bin samples are analyzed the slate and shale are mixed according to the following formula,

$$X = \frac{MR_1 - S_1}{S_2 - MR_2} Y,$$

where M = silica-alumina-ratio desired;
S_1 = per cent SiO_2 in slate;
S_2 = per cent SiO_2 in shale;
R_1 = per cent R_2O_3 in slate;
R_2 = per cent R_2O_3 in shale;
X = shale to be used;
Y = slate to be used.

Either one of the latter is fixed by the scale limits.

The actual mixing is performed by drawing the slate and shale from the bottoms of the bins through a chute into screw conveyors, which convey the materials to elevators at the ends of the sample

bins. These elevators dump the materials into two storage hoppers. These storage hoppers are provided with two hopper bottoms each, provided with valves immediately over the weighing hoppers. There are two weighing hoppers for each material, so that one can be filling while the other is unloading, making the process continuous. By suitable valves on the weighing hoppers, it is possible to discharge the two materials into the screw conveyor beneath at the proper rate, which is an important factor in such a method of mixing.

From the scale hoppers the mixed material is elevated and conveyed to a storage bin above the "clay" scales where it is mixed with limestone.

The composition of the clay mixture is determined and is mixed with the limestone by the following formula,

$$X = \frac{S_2M - L_2}{L_1 - S_1M} Y,$$

where X = weight of limestone;
Y = weight of clay;
M = lime factor or "Hydraulic Modulus";
S_1 = per cent SiO_2 plus per cent R_2O_3 in limestone;
S_2 = per cent SiO_2 plus per cent R_2O_3 in clay;
L_1 = per cent CaO in limestone;
L_2 = per cent CaO in clay.

The limestone used is a very pure limestone, so that the clay matter introduced with it is so small that it seldom interferes with the silica-alumina-ratio established by the slate and shale mixing.

In arriving at our present standard of mixing we have been handicapped by not having the necessary instruments and apparatus to record the actual facts connected with each series of experiments. During the time that these experiments were in progress it was necessary to change coals several times, so that we could not make any definite thermal comparisons. On account of climatic conditions and our method of drying, it was at times impossible to grind the final mix to the proper degree of fineness. Nevertheless, the results of these experiments have been such that we feel con-

fident that future improvements will not change our present standard to any appreciable extent.

By our present standard of mixing the value of M in slate and shale mixing $= 2.40$ and in the final mixing with limestone $M = 1.91$.

When the final mixture is ground so that 97 per cent can be washed through a No. 100 sieve, and properly burned, the cement produced seems to be in chemical balance, possessing all the characteristic qualities of the highest grade Portland cement and with no erratic or freakish features.

With the few changes that are to be made in the drying and grinding of the raw materials we will be able to produce a cement that is absolutely uniform in composition and quality, and one whose active elements are at all times under perfect control.

When cement manufacturers realize the numerous advantages that this system of control possesses, I believe that it will come into general use.

Every manufacturer and user of cement realizes the importance of uniformity, and in order to produce a uniform cement the raw materials must necessarily be uniform. With this method of clay control we are able to produce a perfectly uniform clay and, in a measure, correct the variations of the marl or limestone.

Since writing this paper a change has been made in the process of handling the clay mix which has proved to be a decided improvement over the old method. The change consists in grinding the mixture of slate and shale before adding the limestone. This insures fine grinding of the clay content in the final mix and does away with extreme fine grinding of the final mix with better constancy of volume tests on the resulting clinker. The grinding is done in a 5×22 Gates tube mill, and the fineness averages $96\frac{1}{2}\%$ passing a No. 100 mesh sieve.

COLLOIDS AND THE ULTRAMICROSCOPE

By JEROME ALEXANDER

Read at the Brooklyn Meeting, June 24, 1909

1. The Ultramicroscope and Some of its Revelations

It is a matter of every-day experience that the unseen motes and dust particles in the air become visible in a beam of bright light, especially against a dark ground; and in this simple fact lies the principle of the ultramicroscope.

Faraday,* and later Tyndall, made use of a convergent beam of light to demonstrate the optical inhomogeneity of solutions, for, in fluids not optically clear, the path of the beam becomes more or less distinctly visible, because of the light scattered by the particles present. In this manner can be recognized much smaller quantities of matter than by spectrum analysis—in fact, less than 10^{-8} mg. (1/10,000,000 mg.) of metallic gold can thus be detected with the naked eye.

Professor Richard Zsigmondy while experimenting with colloidal solutions, conceived the idea of examining this light cone microscopically. His preliminary experiments having demonstrated that he could thus see the individual particles in various hydrosols, he sought the assistance of Dr. H. Siedentopf, scientific director of the Carl Zeiss factory in Jena, where was produced the first efficient ultramicroscope.

The ultramicroscope consists essentially of a compound microscope arranged for examining in a dark field an intense convergent beam of light cast within or upon the substance under examination. The light seen by the eye represents therefore the light diffracted, scattered, or reflected upward by the substance or by particles within it.

If within a thin beam of light from the projection lantern we scatter successively powders of different substances in various

* Phil. Trans., 1857, p. 154.

degrees of fineness (mica ground to pass 60, 100, and 160 mesh; lampblack; powdered oxide of zinc; flake and powdered graphite), some of them will produce only a homogeneous illumination of the beam in which no isolated particles can be seen, whereas with others the individual particles are distinctly visible.

Passing the beam through a beaker of distilled water, nothing can be seen, but upon the addition of a few drops of a colloidal gold solution, which appears quite clear to transmitted light, the path of the beam through the fluid immediately becomes visible. This Tyndall effect, as it is called, might be considered a criterion of colloidal solution were it not that very minute traces of colloidal impurities can produce it, and it is besides often exhibited by solutions generally regarded as crystalloidal—those of many dyestuffs, for example. Besides, with increasing fineness of subdivision the Tyndall effect decreases, disappearing as molecular dimensions are approached.

Just as in the cosmic field our most powerful telescopes fail to resolve the fixed stars, which are nevertheless visible as points of light of varying brilliancy, so too in the ultramicroscopic field we can see particles much smaller than the resolving power of the microscope (that is, smaller than a wave length of light), provided only that they diffract sufficient light to affect the retina. Based upon the experience of astronomers we may be able greatly to increase the sensitiveness of the ultramicroscope by fortifying the eye, so to speak, with the photographic plate, using at the same time tropical sunlight or ultraviolet light for illumination.

In the original form of the ultramicroscope as perfected by Siedentopf and Zsigmondy, which is the one best adapted for the examination of fluids and transparent solids, a side illumination is effected by a microscope objective with micrometer movements, which throws an intense but minute conical beam of light into the fluid contained in a little cell having quartz windows at the side and top. Above this cell a compound microscope is adjusted vertically so that the narrowest part of the light cone occupies the center of the focal plane. If the fluid under examination be optically clear or if it contain particles so small that they cannot diffract sufficient light to create a visual impression, the light cone cannot be seen. If enough light is diffracted, the light cone becomes visible, being homogeneous if the particles are

too small or too close together to be individually seen, and heterogeneous if the particles can be individually distinguished. Particles or dimensions beyond the resolving power of the microscope (about $\frac{1}{4}\mu$ *) are for brevity termed ultramicrons. Ultramicrons that can be individually made visible are called submicrons (or hypomicrons), while those so small that they produce an unresolvable light cone are termed amicrons.

In the ultramicroscope I have arranged a piece of faintly colored gold ruby glass, which as you can see is red to transmitted and green to reflected light. Upon darkening the room and throwing a beam from the arc light into the apparatus, the individual particles of gold which give the glass its color become visible as brilliant points in a dark field.

Knowing the percentage of gold present, and assuming a certain specific gravity and uniform shape for the gold particles, the average size and mass of a single particle can be calculated if the number present in a given volume is first counted. In this manner Zsigmondy has shown that the smallest particles of colloidal gold which can be individually distinguished with bright sunlight, are approximately $5\mu\mu$ † in diameter, that is five millionths of a millimeter; still smaller particles exist, but they produce only an unresolvable light cone. Magnified 1,000,000 times such a tiny gold particle would be about $\frac{1}{4}$ of an inch in diameter, while a human red blood corpuscle would be about 25 feet across, and a hydrogen molecule a speck barely visible. The gold particles in the unresolvable light cone must therefore closely approach molecular dimensions. In fact, by allowing amicrons to grow into visibility in a suitable solution and then counting them, Zsigmondy has recently shown that some of the particles of colloidal gold have a mass of $1-5.10^{-16}$ mg., indicating a size of 1.7 to $3\mu\mu$.

Most interesting is the fact that the ultramicroscopic particles of aqueous colloidal gold possess a motion so rapid and extensive that the well-known Brownian movement of small particles is insignificant in comparison. The tiniest gold particles visible have an amplitude of translation of 10μ and over; and the smaller the particles are, the more rapidly they move. The rushing, whirling swarm of particles revealed by the ultramicroscope in

* $1\mu = \frac{1}{1000}$ mm. † $1\mu\mu = \frac{1}{1,000,000}$ mm.

colloidal solutions is, so to speak, a visible demonstration of the kinetic theory, for we can easily imagine what is taking place in gases and in crystalloid solutions where the particles are much smaller and more numerous, and move with correspondingly greater velocity.

Before exhibiting to you in the instrument some metal hydrosols, I must repeat what Zsigmondy wrote on first observing the motion of the tiny gold particles, the smallest of which move from 100 to 1000 times their own diameter in $\frac{1}{6}$ to $\frac{1}{8}$ of a second. Conceiving colloidal gold as a suspension, one might, he said, be led to imagine that its particles would float quietly or at most show only the slight Brownian movement.

"How erroneous is the idea! The little gold particles no longer float, they move—and that with astonishing quickness. A swarm of gnats dancing in a sunbeam will give one an idea of the motion of the gold particles in the hydrosol of gold. They hop, dance, jump, dash together and fly apart, so that one can hardly keep one's bearings in the whirl." *

The particles also have color. Speaking of a yellowish-brown solution of colloidal silver, prepared by Bredig, Zsigmondy says: "One can hardly imagine what a beautiful color play is exhibited by this unsightly fluid upon ultramicroscopical examination. Blue, violet, yellow, green, and red particles in various shades and rare brilliancy of color move in endless array. One particle approaches another, circles it in rapid zig-zag motion, and is dashed away again; sometimes one follows another until they almost touch, without reaching it. Often several group together and dance like gnats in the sunshine, especially when for the fraction of a second one particle approaches another."

The effectiveness of the ultramicroscope depends upon the specific intensity of the source of illumination. The best results are therefore to be obtained by using sunlight, which on a bright clear summer's day with the sun at high altitude, is about ten times more powerful than the arc light we have here to-day, which will simply give an idea of what can be done under better conditions.

* "Colloids and The Ultramicroscope," John Wiley & Sons.

2. Colloid Chemistry and Some of its Practical Applications

The father of colloid chemistry was an Englishman, Thomas Graham, F.R.S., Master of the Mint. In two basic papers on this subject, the first entitled "Liquid Diffusion Applied to Analysis" read before the Royal Society of London, June 13, 1861, the second, "On the Properties of Silicic Acid and other Analogous Colloidal Substances," published in the Proceedings of the Royal Society, June 16, 1864, Graham pointed out the essential facts regarding colloids and the colloidal condition, and established most of the nomenclature in use at the present day. Even now on re-reading his papers, we cannot but marvel at the manner in which his ideas have been confirmed by recent research.

At the beginning of the second paper just referred to Graham stated: "The prevalent notions respecting solubility have been derived chiefly from observations on crystalline salts, and are very imperfectly applicable to the class of colloidal solutions." From this it may be seen that Graham appreciated the fact that all the laws of crystalloidal solutions could not be applied to colloidal solutions. In the case of crystalloidal solutions the dissolved substance is present in a state of molecular subdivision, and, according to the ionization theory, is in many cases dissociated into ions. With colloidal solutions, on the other hand, we have a lesser degree of subdivision, and the particles in solution are larger and more cumbersome. As Graham remarked: "The inquiry suggests itself whether the colloid molecule may not be constituted by the grouping together of a number of smaller crystalloid molecules, and whether the basis of colloidality may not really be this composite character of the molecule." This is to-day the idea generally accepted.

Colloid chemistry deals with the behavior and properties of matter in the colloidal condition, which, as we now know, means a certain very fine state of subdivision. While there are no sharp limitations to the size of particles in colloidal solutions, it may in a general way be stated that their sphere begins with dimensions somewhat smaller than a wave length of light, and extends downward well into dimensions which theory ascribes to the molecules of crystalloids.

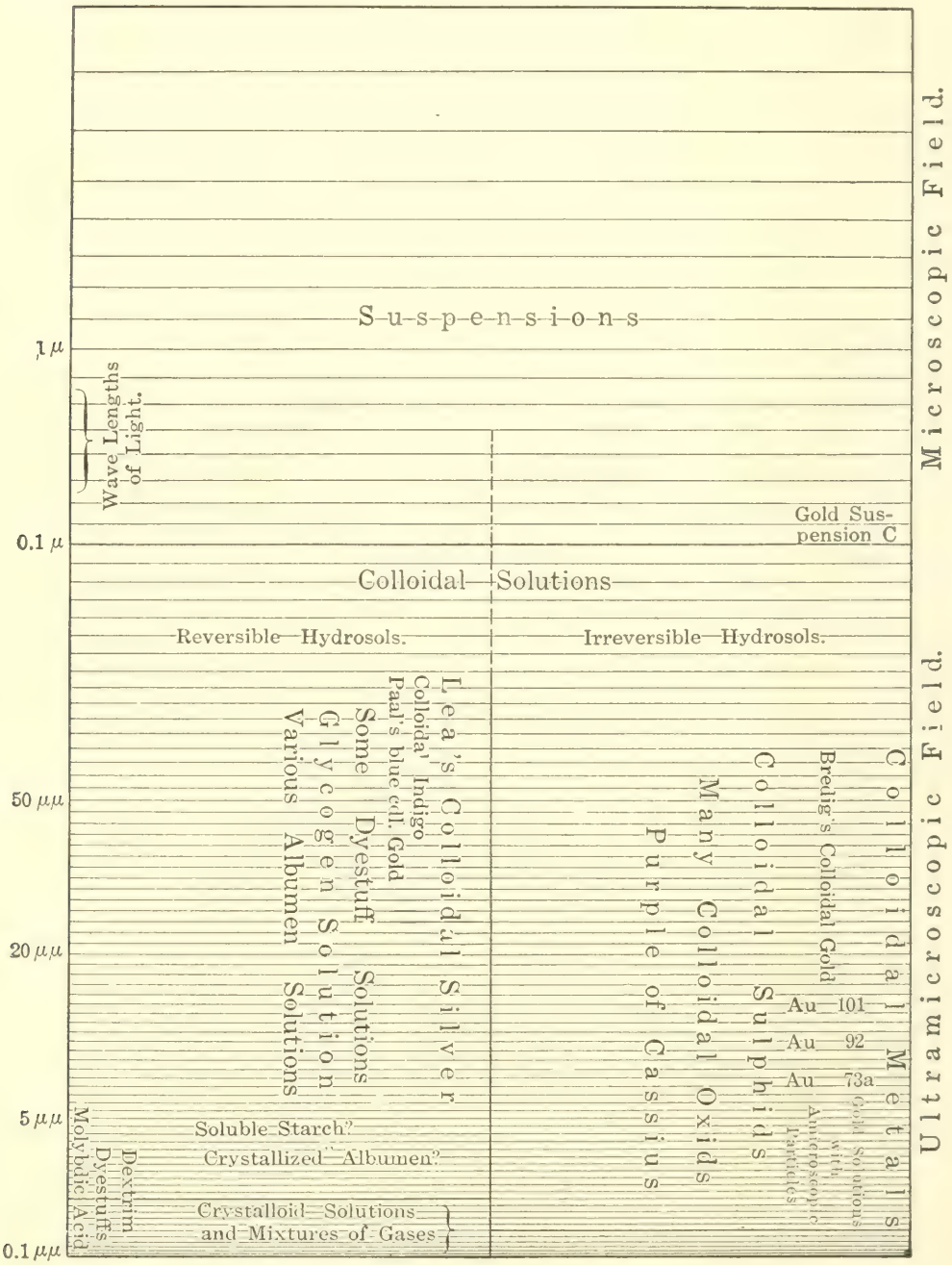
It is evident, therefore, that colloidal particles are beyond the

range of microscopic *resolvability;* but they can nevertheless be *rendered visible.* An instrument for this purpose, the ultramicroscope, was devised by Zsigmondy, who, with its aid, was the first to see the individual particles in colloidal solutions and establish their size. In the case of metallic gold, for example, Zsigmondy found that subdivisions of the metal having particles larger than about 80$\mu\mu$ acted as suspensions and deposited their gold, whereas finer subdivisions exhibited the properties of colloidal solutions. Because in some cases colloidal particles have been whizzed out of solution in a high-speed centrifugal, it has been proposed to apply the term "colloidal suspensions" to such solutions on account of their manifest lack of homogeneity. But it must be remembered that even crystalloid solutions are not homogeneous, as is made evident by an experiment of Van Calcar and Lobry de Bruyn, who caused saturated crystalloid solutions to crystallize at the periphery of a rapidly rotating centrifuge.

As the subdivision of a substance proceeds, the influence of gravity which in the case of true suspensions is paramount, yields gradually to the influence of surface tension, the electric charge of the particles, and other forms of energy. The larger particles in suspension float quietly or else show the well-known Brownian movement; but the particles of colloidal solutions show the active motion before referred to which really keeps the particles of colloids in solution.

Specific properties of the subdivided substance exercise such a potent and variable influence upon colloidal solutions, that a satisfactory classification has proven difficult. Perhaps the best classification proposed is that of Zsigmondy, who, developing the system of Hardy, classifies colloids according to the size of their particles, and divides them into the reversible and the irreversible hydrosols, the former redissolving after desiccation at ordinary temperature, whereas the latter do not. The following diagram taken from Professor Zsigmondy's book, "Colloids and the Ultramicroscope" (Zur Erkenntnis der Kolloide), will make this quite clear.

In colloids and crystalloids we have, as Graham aptly remarked, "two different worlds of matter"; and these differences are consequent, not upon chemical constitution, but upon the characteristic difference in the size of their ultimate particles. As the particles of colloids approach molecular dimensions, the so-called



Comparative Size of Colloidal Particles

"molecular" and "chemical" forces begin to assert themselves and finally dominate the resulting phases. It is difficult, therefore, to draw a sharp line between chemical and physical reactions, and we can easily understand how mixtures of colloids or "colloid compounds," as they are now called, have in the past been mistaken for chemical compounds. Thus the purple of Cassius which Berzelius regarded as a chemical compound, is a mixture of colloidal gold and colloidal stannic acid, as Zsigmondy has demonstrated by actually synthesizing it. Mention may also be made of many so-called "hydrates" which van Bemmelen has proven to be oxides containing absorbed (or adsorbed) water. Even in his first paper Graham had compared the water of crystallization with the water of "gelatination," remarking: "The water in gelatinous hydrates is aptly described by M. Chevreul as retained by capillary affinity; that is, by an attraction partaking both of the physical and chemical character."

In addition to the simulation of chemical compounds just referred to, some of the other properties of colloids which have practical significance are the following:

Electric Migration. Under the action of an electric current the particles of colloidal solutions give evidence of their electric charge by moving toward the electrode of opposite polarity. Ferric and aluminium hydroxides are positively charged and move toward the cathode, while colloidal metals, tannin, gelatin, etc., are negatively charged and move toward the anode.

Mutual Precipitation. As a general rule oppositely charged colloids precipitate each other; but a difference of charge is not essential, as is evidenced by the fact that tannin precipitates gelatin. This mutual precipitation is influenced by many conditions; thus, upon adding gum arabic solution to certain dyestuff solutions, a prompt coagulation took place, whereas upon adding the color gradually to the gum solution no precipitation occurred.

Pectization and Peptization. Pectization means the coagulation of a hydrosol, and peptization its re-solution. In general, it may be stated that whatever tends to favor flocculation or group formation favors pectization, but in each case specific influences govern. As examples may be mentioned the addition of flocculating crystalloids, desiccation, and cooling, all of which tend to produce gel formation. One the other hand, traces of

certain substances may cause a gel to revert to a sol, as in the case of colloidal stannic acid gel, which is fluidified by a few drops of ammonia. (See Zsigmondy, loc. cit., chapter 21, for a discussion of these phenomena.)

Impermeability to Other Colloids. Remembering that the individual particles of colloids are larger and more sluggish than those of crystalloids, it is at once evident why colloids do not readily impenetrate each other, and since colloids differ widely with respect to the size of their particles, it will also be seen that they must differ greatly in their diffusibility, a fact first pointed out by Graham, and recently illustrated by the beautiful work of Bechhold on ultrafiltration.

Protective Action. Briefly stated, protective action means the property possessed by most reversible colloids of opposing group formation, flocculation, and crystallization; and this property has, as we shall see, many very important practical applications. Two simple experiments will serve to illustrate it.

Divide a dilute solution of lead nitrate between two glasses, and after adding to one portion some glue or gelatin solution, place in each glass a strip of ordinary sheet zinc. After the lapse of a few minutes brilliant crystals of lead will be seen on the strip of zinc in the glass in which no colloid is present, whereas the zinc in the glass with the glue will show a blackish-looking amorphous deposit.

Again in the presence of gelatin, the usual precipitate of silver chloride is not formed, only an opalescence resulting which completely passes through filter paper.

As a consequence of protective action, reversible colloids possess the interesting property of rendering irreversible colloids reversible. A capital instance of this effect is found in pure colloidal gold which, by as little as one ten-thousandth of one per cent of gelatin, is protected from coagulation and the concomitant color change from red to blue.

With chemical compounds we always have definite combining proportions, whereas with colloid compounds the proportions vary according to conditions; so that many phenomena which could find no satisfactory chemical explanation yield readily to the principles of colloid chemistry.

Some practical applications of the principles above referred to have been given in a paper read before the Society of Chemical

Industry, and besides referring to several of these, I shall try to explain some more recent observations.

Boiler Compounds. The problem of preventing the formation of scale in boilers has been attacked by chemists chiefly by the use of various salts intended to precipitate scale-forming constituents of the feed-water. In addition to such salts, most formulæ for "boiler compounds" include such ingredients as glue, dextrin, potatoes, extract of hemlock, etc., the value of which was appreciated by practical people, although no scientific explanation of their efficacy was offered. These colloids undoubtedly tend to prevent the formation of hard crystalline scale, either by inhibiting to some extent the precipitation of scale-forming substances, or else by keeping the precipitate in an extremely fine non-crystallizing condition.

Clay and Pottery. In recent years many patents have been taken out for the use of tannin and similar vegetable substances in rendering clay more plastic, and also stronger when baked. In French patent 376,333 (April 3, 1907), the use of extract of straw is specifically mentioned, which is interesting in view of the fact that in the Bible (Exodus v) it is mentioned that brick cannot well be made without straw.

These effects, together with the well-known superior sizing properties of glue and similar colloids which "free out" clay and make it "cover" in surfacing paper and in kalsomining, are readily explained by the property possessed by reversible colloids of opposing group formation and thus producing an extremely fine-grained condition.

Agriculture. Many important properties of solids, such as permeability, capillarity, absorption, moisture content, etc., are dependent not so much upon the chemical composition as upon the size of the constituent soil particles.* In coarse sand, for example, the amount of water is greatest at the bottom and smallest at the top, whereas in fine clay the distribution is much more uniform.

Among the natural agencies tending to increase the size of the *minute* soil particles may be mentioned heat with its drying or evaporative effect, freezing, and the coagulating or flocculating

* See Atterberg, Schwed. Landw. Akad., 1903, and Chem. Ztg., 1905, 29, 195; Patten and Waggaman, U. S. Dept. of Agri., Bureau of Soils, Bull. 52, 1908.

action of soluble inorganic salts and of some organic substances present in the soil. On the other hand, included in that little-known class of substances vaguely described as "humus," there are numerous organic substances derived from bacterial, plant, or animal débris, or exuded by the roots of plants, which act as protective colloids (schutzkolloide), and tend to produce and maintain the hydrosol, diffuse or deflocculated condition.* In an excellent paper on the mechanics of soil moisture, L. J. Briggs † pointed out that very small quantities of certain organic substances such as are continually being produced in the soil by the decay of organic matter, greatly decrease the surface tension of solutions, thus counteracting to a large extent the effects of the surface application of soluble salts which would tend to draw moisture to the surface by increasing the surface tension of the capillary water of soils. It is well known, however, that an excess of salts will ruin a soil physically, as is evident after flooding by sea water or the continuous application of chemical fertilizers.

Of interest in this connection is the recent work of the Bureau of Soils, U. S. Dept. of Agriculture, carried out by Cameron, Schreiner, Livingston, and their coworkers. Thus in the case of the unproductive Takoma soil, green manure, oak leaves, tannin, and pyrogallol greatly benefited plants grown in it. The injurious effects of quinone and some other organic substances may be due to their ability to precipitate or flocculate the protective colloids of the soil; for as Lumière and Seyewetz ‡ have shown quinone renders gelatin insoluble.

The fact observed by Fickenday § that more alkali is required to flocculate natural clay soils than kaolin suspensions, he attributes to the protective action of the humus present.||

Electroplating and Electrodeposition of Metals. The addition of protective colloids to electroplating baths tends to keep the desposited metal very fine-grained and non-crystalline, thus improving the strength and appearance of the deposit. This princi-

* See P. Ehrenberg, "Die Kolloide des Ackerbodens," Zeit. f. ang. Chem., 1908, 14, 2122.

† U. S. Dept. of Agri., Bureau of Soils, Bull. 10, 1897.

‡ Bull. Soc. Chim., 1907, 4, 1, 428–431, J. S. C. Ind., 26, 703.

§ J. Landw., 1906, 54, 343.

|| See Keppeler and Spangenberg, J. Landw., 1907, 55, 299, Chem. Abs., 1908, 2, 1025.

ple is illustrated by the experiment with lead nitrate previously referred to.

Metallurgy. There is some evidence that the fine-grained structure of some steels is due to the inhibition of crystallization by substances colloidally dissolved in the molten mass. The effect of sudden chilling upon structure is illustrated by the experiments with soap (see below).

Dyeing. In addition to the discussion of this subject in my paper above referred to, I must mention a few recent experiments.

Dreaper and Wilson * in a paper entitled "Reactions between Fibers and Dyes," have given the results of some observations on the changes in color produced in fibers dyed with sensitive dyes, upon the immersion of these fibers in acid of varying strength. Their results showed that under like conditions the color changes of the animal fibers—silk and wool—were of a different order from those of cotton, which latter appeared to follow fairly closely those of solutions.

Some time previously I had observed that Orange II when precipitated by barium chloride in the presence of a little gelatin gave a much redder shade than the same color precipitated in the presence of the colloid. Not only is the shade different, but so is the whole nature of the precipitate, the former being compact and settling out, the latter being gelatinous and remaining in suspension. Consequently it occurred to me that the variation in the effects of the different fibers might be due to their difference in protective action on the adsorbed dye. I therefore made some experiments with *solutions* of benzopurpurin, and found that the addition of protective colloids completely altered the nature of the color changes brought about by acid, making these changes of the same order as those of wool dyed with benzopurpurin.

While I have not yet been able to make any quantitative experiments, I may mention that in the case of a pure dilute solution of benzopurpurin, the addition of dilute mineral acids quickly changed the color from bright red to dark blue, reminding one of the change of pure colloidal gold. Stronger acid coagulated the dye, which settled out from the solution; neutralization of the acid with alkali redissolved the precipitated dye with a restoration of the original color.

* J. Soc. Chem., vol. 28, p. 57.

The same solution of benzopurpurin, to which gelatin or gum arabic had been added, gave with dilute mineral acids a claret-red solution, more concentrated acid changed the shade to a chocolate brown without, however, causing any precipitate.

The fact that organic acids (acetic and tartaric) are less potent than mineral acids in producing color changes is probably due to their lesser degree of dissociation; for the H ions are mainly responsible for flocculation. The restraining influence of salts also mentioned by Dreaper and Wilson may in part be due to their prevention of dissociation of the acid used.

I propose to examine these color changes with the ultramicroscope.

Soap. The views of Merklen on the colloidal nature of soap have been epitomized by Lewkowitsch in his paper entitled, "Modern Views on the Constitution of Soap," substantially as follows:

Commercial soap is a product having an essentially variable composition dependent upon (1) the nature of the fatty acids, (2) the composition of the "nigre" (in the case of settled soaps), (3) on the temperature at which the boiling is conducted; it behaves like a colloid, and should not be regarded as a compound of sodium salts of fatty acids with which a definite amount of water is combined chemically, but rather as an "absorption-product" whose composition is a function of the environment in which the salts of the fatty acids happen to be at the moment of the finishing operation.

In this connection I must make mention of the excellent paper by W. D. Richardson * on transparent soap, which he terms a supercooled or supersaturated solution, having distinctly crystalline tendencies, and exhibiting colloidal properties. Having in mind the fact that the salts of the higher fatty acids dissolve in water as colloids, and in alcohol as crystalloids, † and also the fact that alcohol or equivalent solvents (glycerol, sugar, etc.) are used in transparent soap, it seems probable that the crystals which frequently form in it are due to the slow separation of such part of the soap as is in crystalloid solution. This view is supported by the fact adduced

* J Am. Chem. Soc., 30, 414.

† S. Ya. Levites, Zeit. Chem. u. Ind. Kolloide, 2, 208 et seq., Chem. Abs., 2, 2482; Mayer, Schaeffer and Terrome, Compt. rend., 146, 484, Chem. Abs., 2, 1626.

by Richardson (loc. cit., p. 418) that the fatty acids separated from the crystals had a higher melting point than those separated from the clear matrix. What we may call the crystalloid phase of soap is apparently governed by the same factors as those which Tamman has pointed out as governing the crystallization of supercooled solutions, i.e., (1) the specific power of crystallization; (2) the speed of crystallization; (3) the viscosity (see Zsigmondy, p. 128 et seq.). Thus gold ruby glass when quickly cooled (or supercooled) is colorless, but acquires a red color upon reheating to the softening point. By ultramicroscopic examination Zsigmondy showed the nucleii of metallic gold which in the colorless glass were amicroscopic, grew into ultramicroscopic visibility in the red glass. It therefore seemed to me that a most important factor in determining the transparency of transparent soap would be the speed of cooling, and some experiments were made along this line.

A piece of commercial transparent soap was melted and cast into two cups, one of which was quickly chilled in ice, while the other was allowed to cool slowly by immersion in hot water. The quickly cooled piece was transparent, while the other was practically opaque and showed upon ultramicroscopic examination much larger ultramicrons than the transparent piece.

Since writing the above, I again examined the slides after they had stood three or four months. To the naked eye, the quickly cooled soap was still transparent, whereas large opaque spots could be seen in the slowly cooled piece. In the ultramicroscope the former appeared as before, whereas the latter showed large and perfectly resolvable crystals in a clear matrix.

Milk. That casein exists in milk as an irreversible colloid and can be protected by reversible colloids ("schutzkolloide"), I have shown by the following experiment: Skim milk was diluted with water and divided into two parts, to one of which was added a little liquid glue or gelatin. The two solutions were placed in boiling tubes and acidified slightly with acid (acetic or muriatic). The tube without the added colloid cleared up rapidly, the precipitate formed, rising to the top and leaving the fluid beneath quite clear. The tube containing the added colloid, while eventually showing some precipitate, remained milky even after several weeks' standing. Since writing the above, the ultramicroscopic observation of Kridl and Neumann * also support the conclusion that the casein

* Physiol. Inst. Univ. of Vienna [Pfluger], 123, 523–39, Chem. Abs., 2, 3093.

of milk is an irreversible hydrosol. I can also confirm the observation of these investigators that with arc light the individual particles of the casein in cow's milk are visible in the ultramicroscope, whereas those of woman's milk are not visible.*

This view has an important bearing on the question of the modification of cow's milk for infant feeding, for it justifies the addition of reversible colloids such as cereal gruels, gelatin, etc., which had been opposed by some physicians on the ground that they were not normal constituents of mother's milk, or any other milk. But experiment shows that the curd resulting from the coagulation of human milk is much softer and more readily digested than that yielded by cow's milk, which, as an inspection of the subjoined table will show, indicates that the so-called albumen of woman's milk acts as a protective colloid.

TABLE III

AVERAGE COMPOSITION

	Casein.	Albumen.	Total Proteids.	Fat.	Milk-Sugar.	Ash.
Cows' milk	3.02	0.53	3.55	3.64	4.88	0.71
Human milk	1.03	1.26	2.29	3.78	6.21	0.31
Goats' milk	3.20	1.09	4.29	4.78	4.46	0.76
Ewes' milk	4.97	1.55	6.52	6.86	4.91	0.89
Mares' milk	1.24	0.75	1.99	1.21	5.67	0.35
Asses' milk	0.67	1.55	1.64	1.64	5.99	0.51

To physicians it is certainly no novel statement that the addition of reversible colloids to milk very much increases its digestibility. Thus Dr. A. Jacobi † says: "There is no doubt, therefore, as to the utility of gum arabic and gelatin as an addition to cow's milk and to children's diet. Not only do they fulfill the indication of diminishing and distributing the particles in cow's milk, but they also officiate as a means of direct nourishment by preventing waste." He also points out that "it was evident that the other ingesta were more completely digested, and that a smaller amount of excrementious matter was discharged when gelatine was added than when omitted."

* See also Alexander and Bullowa, Archives of Pediatrics, vol. 27, p. 18, and Alexander, Zeit. f. Chem. und Ind. Kolloide, 1909 and 1910, and J. Am. Chem. Soc., May, 1910.

† "The Intestinal Diseases of Infancy and Childhood" [1890], p. 62 et seq.

In this case the added "protective" colloids act by preventing the formation of large groups when the casein is coagulated by the acid juices of the stomach, so that the precipitate (if at all formed) is readily dissolved by the digestive enzymes. In fact, it may be that the coagulation of the casein is entirely prevented, for Dr. Jacobi remarks that milk, when mixed with gum arabic, bears the admixture of muriatic acid quite well. In his book on the "Diseases of Infancy and Childhood," 1902, Dr. H. Koplik states:

"The amount of casein in cow's milk is not only relatively, but absolutely greater than in woman's wilk. In describing woman's milk it was stated that in cow's milk the casein forms five-sixths of the total proteids in the milk, whereas in woman's milk the casein forms two-sixths of the total proteids. This fact is of far-reaching importance. Simple dilution of cow's milk leaves it with a greater proportion of casein relatively to the other proteids than that which exists in human milk. Again, cow's milk precipitates or coagulates very early with the aid of acids and salts, woman's milk quite late, or not at all. Therefore, in the infant stomach cow's milk does not take up much acid of the gastric juice and soon coagulates in large masses. Woman's milk, on the other hand, takes up a large amount of acid of the gastric juice, and coagulates late in small masses. These differences in the modes of coagulation in the two caseins are of great importance in the study of infant feeding."

Further investigation is being made as to the nature of the chemical composition and the condition of subdivision of the casein in various milks, which have been assumed to be chemically different. Many reactions which have been held to indicate such chemical difference may be simply due to the presence of varying amounts of protective colloids or to differences in the colloidal condition or aggregation of the same casein, consequent to some extent, perhaps, upon differences of reaction, or quantity of salts or enzymes present.

The observation of Gerber and Berg * that the albuminoids of milk exercise a retarding influence upon its coagulation by rennet enzymes, and also the observation of Bergell and Langstein † that the casein from human milk contains much less phos-

* See Chem. Abs., 1909, vol. 3, p. 548.

† Chem. Abs., 1909, vol. 3, p. 663, Jahrb. Kinderheilk., 68, 568.

phorus than does that obtained from cow's milk, and loses a large portion of it when washed thoroughly with hot water, whereas the casein from cow's milk does not lose any phosphorus under these conditions, are both readily explained in the light of the principles above set forth. In the latter case the protective action of the albumen has apparently left the precipitated casein more soluble.*

Filtration. The importance, in technical filtration, of the relation between the size of the particles of a precipitate and the size of the orifices in the filter has been pointed out by E. Hatschek.† It is quite evident that the presence of protective colloids by tending to produce the fine or "hydrosol" condition may entirely prevent the filtration of a precipitate by ordinary means, and for this very reason the filtration of glue and gelatin liquors is practically impossible unless a flocculated "hydrogel" precipitate is first obtained. The work of Zsigmondy and Schulz ‡ on the filtration of gold hydrosols is of particular interest in this connection.

Chemical Analysis. The presence of colloids, especially in technical products or solutions, may lead to grave errors in analysis, so that the chemist should destroy them by ignition, or else nullify their effects by the addition of a sufficient excess of coagulant or precipitant. Reversible colloids, which are frequently referred to under the vague term "organic matter," may act:

1. By totally or partially preventing the formation of precipitates, just as tartaric acid and tartrates prevent the precipitation of Al, Cr and Fe. §

2. By preventing the satisfactory filtration of the precipitate formed. ||

3. By rendering precipitates difficult to wash and purify.¶

A few experiments will serve to make clear the importance of these remarks. Three solutions of acetate of lead were taken; to the first was added HCl, which yielded a heavy coagulated precipitate; to the second was added $BaCl_2$ (a less highly ionized

* See also Alexander, Zeit. Chem. Ind. Koll., 1909 and 1910.

† J. Soc. Chem. Ind., 1908, 27, 538.

‡ See "Colloids and The Ultramicroscope" by Zsigmondy. See also Bechhold, Z. Chem. und Ind. Koll., 1906, 1, 107, Z. physik. Chem. 1907, 60, 257; Biochem. Z. 6, 679; Bigelow, J. Am. Chem. Soc., 29, 1675; J. Soc. Chem. Ind. 27, 93.

§ See Yoshimoto, J. Soc. Chem. Ind., 1908, 27, 952.

|| See Mooers and Hampton, J. Am. Chem. Soc., 30, 805.

¶ See Duclaux, J. Soc. Chem. Ind., 1906, 25, 866.

precipitant) which yielded a colloidal precipitate of $PbCl_2$; to the third was added first a little glue solution and then $BaCl_2$, which in this case gave no precipitate at all.

Any number of experiments of this kind can be made; among those I have found of interest are:

Sodium thiosulphate	+	colloid	+	HCl
$CaCl_2$	+	colloid	+	Ammonium oxalate
Lead acetate	+	colloid	+	$ZnSO_4$
Lead acetate	+	colloid	+	KI
Lead acetate	+	colloid	+	$K_2Cr_2O_7$
$MgSO_4$	+	colloid	+	$BaCl_2$
Potassium ferrocyanide	+	colloid	+	$CuSO_4$
$FeCl_3$	+	colloid	+	NH_4OH
HCl	+	colloid	+	Sodium thiosulphate

Colloidal principles are of particular importance to physiological chemists, as may be seen for example from the excellent monograph of W. M. Bayliss on "The Nature of Enzyme Action." In this connection, I may mention a simple experiment which will serve to illustrate the part taken by tissues in body-reactions. A one per cent solution of agar containing a little phenolphthalein and potassium ferrocyanide, was made pink with dilute ammonia and allowed to set to a jelly in a test tube; when it had set, a solution of ferric chloride was poured on top. After standing a few days, the tube was pink at the bottom, colorless in the middle and blue at the top, showing that the chlorine and the iron had been separated. In fact the same effect can be clearly seen even after the lapse of a few minutes.

So manifold and important are the practical applications of colloid chemistry, that only a few of them could be mentioned in this desultory and very incomplete survey. Its principles are of great importance in brewing, tanning, photography, textile finishing, sugar refining, sewage disposal, concrete construction and many other branches of industry; and the main object of this paper is to direct attention to the importance of colloids and the colloidal condition.

President Sadtler:

I heard last Friday evening a lecture by the President of the American Chemical Society on this same subject. He stated at

that time that ten years ago physical chemistry was the new thing, and that all the enthusiasts rushed into it. Now all these same enthusiasts are running into colloidal chemistry. In the near future there will be a mass of explanation and observation of this class of phenomena, which will throw a great light on many problems of chemistry. We should look upon it, therefore, with a great deal of interest.

Thanks are due to the firm of E. Leitz, who kindly loaned their instruments for exhibition and demonstration.

THE UTILIZATION OF WASTE INDIA RUBBER

By STEPHEN P. SHARPLES

Read at the Philadelphia Meeting, Dec. 10, 1909

Philadelphia was the first place to have an establishment on a commercial scale for reclaiming rubber. It was my good fortune to be connected with this, almost from the very start in 1880, until the system was practically perfected about 1897. I was well acquainted with every difficulty as it arose, and we had many problems to meet. In order to have some little understanding of these problems I have thought it well to give a short history of the subject from the commencement of the manufacture of vulcanized rubber.

This is a question that has occupied the attention of rubber manufacturers from the earliest days of the art. Thomas Hancock in 1820 was the first to attack the problem. He gives a very interesting account in his work on India Rubber, published in 1857, of his early struggles with the subject. He says: "It was not long before the waste cuttings of the rubber began to accumulate fast; and with the then scanty supply in the market, particularly of the kind fit for my use, I foresaw that I should soon be at a loss for suitable material, unless I could find some means for working up the waste, and I at length resolved upon attempting it."

He soon found that if the scrap rubber was dry and warm that when he pressed the fragments together he could obtain a compact mass. In 1824, the *Quarterly Journal of Science, Literature, and the Fine Arts*, says: "Mr. T. Hancock has succeeded by some process the result of long investigation, but which he has not published, in working caoutchouc with great facility and readiness."

But this scrap rubber with which Hancock was working was nothing but the ordinary raw rubber of commerce, such as is now used in every mill where rubber goods are manufactured.

And the problem which he so laboriously solved is but the ordinary preliminary step in the manufacture of all rubber goods. The process has been modified somewhat and the crude machinery employed by Hancock has been replaced by heavy iron rolls, which may be either smooth or corrugated, and which may run at the same speed or one of them may run faster than the other. He also discovered the curious fact that rubber when passed through rollers becomes very hot and soft. This heating is so great that means have to be taken to keep the rolls cool while working the rubber. This discovery that rubber could be massed was the foundation of all modern working processes for the employment of india rubber.

Hancock's waste rubber was merely scrap rubber and contained no other ingredient than pure rubber. In 1839 Charles Goodyear discovered the art of vulcanizing rubber. This disdiscovery was one that made a useful substance out of a product that before that date had only seeming possibilities. This discovery was one of the great discoveries of the last century, and as has been the case with many other great discoveries, the inventor was rewarded with poverty, while others have grown rich by applying his ideas.

The raw rubber waste that now is found in the mills and in the junk shops is a very different article from that called waste by Hancock. It consists of the trimmings of unvulcanized articles. These trimmings are the pieces cut off during the manufacture of the goods. Most articles of wearing apparel which contain rubber have also either a cloth face or backing. The original Mackintosh goods had both a cloth facing and backing. The trimmings from these have the rubber strongly attached to the cloth. In this state the cloth and rubber are both practically worthless. If the cloth is woolen, it is easy to remove. It is treated with hot dilute alkali. After the removal of the fiber the rubber may again be sheeted and is practically as good as the original rubber mass. By the term rubber mass, is understood, the rubber with its usual fillings of earthy matter. Many people have the idea that the addition of chalk, baryta, diatomaceous earth, and talc, and similar materials to the rubber is solely for the purpose of cheapening the articles made from it. This is far from being true. In many instances articles made from pure rubber are worthless, and it is only by combining the rubber with suitable fillers that it

can be used. The advantage of the alkali treatment is that it does not disturb these fillers, and after the reclaimed rubber is washed in the same manner in which raw rubber is washed, by passing it through corrugated rollers over which there is a constant stream of water running, it can be sheeted and dried and is then ready to mix with another batch of the same material. It only requires the addition of a little more sulphur to replace that removed by the caustic alkali. This treatment with hot alkali must not be continued too long, or rather the goods must not be heated too long, as it is found that there is a strong tendency to vulcanize the rubber even at the heat of boiling water.

When the rubber waste contains cotton fiber as well as wool, we have a different condition. Dilute alkali at ordinary temperatures has but little action on vegetable fibers. And we cannot remove the cotton or other vegetable backing. The first use of this rubber waste seems to have been to grind it on friction rolls until the fiber was ground to a powder. Some fresh rubber was then mixed with the mass and it was used in the manufacture of new goods. Sometimes this cloth was treated with dilute acid previous to being ground. One inventor boiled the scrap for twenty-four hours with 4 per cent sulphuric acid. The action of the acid ceased after boiling an hour or two. But at the end of twenty-four hours the rubber was decidedly vulcanized and was much easier to pulverize. When finely ground, cotton fiber makes a fairly good filling for rubber goods. If, however, it is not well ground, the rubber is apt to blister when it is vulcanized. Many of the rubber blankets used during the war of 1861 were made largely out of this ground fiber and rubber, only enough new rubber being added to make the mass work smoothly.

With vulcanized rubber the problem is changed. The rubber after the removal of the fiber can no longer be sheeted. It can be ground to a fine powder, and when so ground, either with or without the removal of the fiber, it has been much used as filler. It was also used in army blankets, and the blankets made from it passed inspection and went into use. But this use was only a limited one, and some method of treating vulcanized waste was early and earnestly sought for. One of the first methods used was invented by H. L. Hall and used by the Beverly Rubber Co. (Patent 19172, Jan. 19, 1858.)

In this process the rubber was first ground to a fine powder

by passing it through fluted or scored rollers. It was then boiled in water for forty-eight hours, when it became reduced to a plastic or gummy state. He proposed to destroy the fiber by limewater or alum. June 22, 1858, Francis Bashnagel, of Beverly, Mass., proposed to heat the rubber for half an hour in a suitable vessel to a temperature of from 150° to 600° F., thereby producing a sticky substance "which has reassumed the elasticity of new rubber."

November 30, 1858, Mr. Hall made a further improvement in his process, the claim of Patent No. 22217, assigned to the Beverly Rubber Co., reading as follows: "The method of restoring waste vulcanized rubber by grinding it to a fine or powdered state or otherwise, then submitting the same in a close or proper vessel to the action of steam direct upon the rubber, or in connection with water, for the space of forty-eight hours, more or less." Aug. 16, 1859, H. L. Hall patented the use of superheated steam for the purpose of restoring waste. Francis Bashnagel patented substantially the same processes as Hall at about the same time. The fiber was not removed by these processes; but the rubber so recovered could be sheeted. Bashnagel discovered that if vulcanized rubber was rolled long enough on heated rolls it became soft and sticky.

Mr. Hayward, one of the pioneers in the rubber business, rotted the fiber, so that it could be more easily ground, with dilute sulphuric acid, but he evidently was afraid to remove the fiber by strong acid.

Up to 1880 no one seems to have undertaken the recovery of rubber on a commercial scale. About this time the late N. C. Mitchell, of Philadelphia, became interested in the subject. He came into possession of a lot of unvulcanized rubber waste, which he treated with acid and reclaimed. Finding this a profitable operation he prepared to continue the business. But he soon found that the supply of unvulcanized waste was very limited, and he turned his attention to vulcanized stock. At that time old rubber boots and shoes were generally thrown on the dump as being utterly worthless. He found that he could obtain an abundant supply of this material at about three cents a pound—that being about as low as the junk dealers could afford to handle it. He used his own method to defiber the waste and the Hall method for softening the rubber. Mr. Mitchell was not a chem-

ist and was not bound by any traditions in relation to chemistry.

He was free to experiment with all kinds of material for removing the fiber; he never knew beforehand whether they would do the business, but that never hindered him from trying them. He found finally that sulphuric acid of from 12 to 25° Bé. would do the work. He could remove the fiber quickly by this acid without removing much of the compounding ingredients and without injuring the rubber, and at a heat a little below that of boiling water. The acid was heated by blowing steam through the mass. This obviated stirring and by this means it was possible to use a much smaller volume of the acid for treating the rubber. After the liquid was heated to its maximum heat there was no further condensation of the steam, and the contents could be boiled for hours without any change in the level of the liquid. The temperature of the liquid during such boiling rarely rises above 98° C., and by careful manipulation it can be kept as low as 92° or 93° C. The nominal boiling-point of 20° Bé. acid is 105° C. The use of weaker acid had already been tried by Haward, and in 1871 A. M. Faure patented the use of 53° to 58° Bé. acid for the same purpose. It is a curious fact that sulphuric acid stronger or weaker than from about 12° to 25° Bé. acts injuriously upon the rubber, while acid of this strength can be used with perfect safety. If acid of the strength proposed by Faure is used the fiber is quickly destroyed, and the rubber is more or less carbonized. The compounds in the rubber, such as chalk, are but little acted upon, as they are practically insoluble in the strong acid. If the very weak acid is used, its energy is mainly consumed in destroying the chalk, converting it into a sulphate of lime, and in this way the acid is quickly neutralized and has but little effect on the fiber. If the acid is used in sufficient quantity to saturate the chalk, it then becomes very difficult to wash the resultant rubber, as it obstinately retains a little of the acid, which, when the rubber is dried, becomes concentrated and destroys the rubber.

When acid of 15° to 20° Bé. is used, it will destroy the fiber in three or four hours, but it does not act on the compounds as does the weaker acid, and much of the chalk remains unchanged. When the resultant rubber is washed and dried, this remaining chalk takes care of any trace of the acid that is not washed out

and the rubber is not injured by the presence of acid. For this reason it is much easier to make a good article of reclaimed rubber from boots and shoes and similar articles than it is from much higher grade articles. Boots and shoes contain on an average about 40 per cent of chalk, of which only about half is converted into sulphate of lime during the reclaiming process.

After this acid treatment the rubber is thoroughly washed and partly dried. That is, all the water that will drain from it is allowed to run away, but it still retains its own weight of water. Afterwards the rubber is subjected to the action of steam or water under pressure for many hours, the pressure varying from 70 to 150 pounds. The process may be considerably shortened by using a pressure of 150 to 160 pounds. The time can also be materially reduced by grinding the defibered rubber to a fine powder before submitting it to the action of steam.

Sometimes a little heavy petroleum is added to the rubber before it is steamed. This becomes thoroughly incorporated with the rubber and serves to keep it soft and pliable after it is sheeted. After this treatment it is found that the rubber has lost all the properties of vulcanized rubber, and it can, after the addition of sulphur, be again vulcanized.

Each manufacturer has his own methods of working, and each one claims to produce a little better article than his competitor, but I have outlined above the substantial steps pursued by all of them with one or two exceptions. The successful introduction of almost all of the processes can be traced back to the Philadelphia Rubber works and the processes and machinery employed by Mr. Mitchell.

About 1900 two different processes were patented for removing the excess of sulphur from vulcanized rubber. For unless this excess is removed when the defibered rubber is subjected to the softening process it is hardened instead of being softened. Boots and shoes contain very little excess of sulphur, so that its removal is not so important as it is in some other classes of goods. By the processes patented in 1900 such articles as inner tubes of bicycles can be treated.

One of these is for the use of sodium sulphite, which has the property of dissolving free sulphur.

$$Na_2SO_3 + S = Na_2S_2O_3.$$

It is also claimed that the sulphite deoxidizes the oxidized rubber,

$$Na_2SO_3 + O = Na_2SO_4.$$

If ordinary defibered scrap is treated with sodium sulphite under a pressure of 70 or 80 pounds for twenty hours, the rubber is softened and made workable by the process, but it is not devulcanized. The free sulphur that is always contained in vulcanized goods has disappeared, but the sulphur of vulcanization still remains. The sodium sulphite has the advantage that it neutralizes any free sulphuric acid that remains in the rubber after it is defibered, and prevents its injurious effects. The reclaimed rubber produced in this way can be used in the manufacture of belting, and similar articles with or without the addition of any fresh rubber, chalk, and other necessary compounding articles being added.

The other new process is the so-called alkali process. By this process the finely ground rubber is submerged in a 3 per cent solution of caustic alkali and heated to 344° F. under a pressure of about 110 pounds of steam for twenty hours. This process will so weaken the fiber that it can be mostly washed away. But the rubber becomes very soft and sticky and is difficult to work. I have no analyses of this product and so I cannot say whether it removes all the sulphur of vulcanization or not. But the treatment does not accomplish anything more than can be accomplished by the aid of steam or hot water heated to the same temperature. I have taken defibered rubber and heated it under steam and water pressure of 160 pounds and produced an article that could be sheeted and vulcanized, and which produced goods which could be stretched to double their length and which when released returned to their orginial form. In this case a little lime was added to the compound to neutralize any acid that might possibly remain in the rubber or be produced by the oxidation of the sulphite.

The alkali treatment for the removal of the excess of sulphur is old. It is mentioned in many of the early patents for reclaiming rubber, and Hancock mentions in one of his early patents the use of sulphite of soda for the same purpose.

In this sketch I have only given the outlines of the chemical part of reclaiming rubber. Mr. Mitchell invented many ingenious

devices to facilitate the mechanical part of the work. The best description of these is found in patents granted about 1889.

Discussion

Mr. Wm. Grosvenor:

There is one process on which Dr. Sharples has not touched, perhaps for the reason that it is not altogether commercial. It has, however, some interest from the chemical point of view. Here is an extremely poor sample of reclaimed rubber obtained in this way; it is about a year old. The process is peculiar and interesting because it produces a solution of rubber in water. Here is an aqueous solution of rubber. It may be called an emulsion, but, so far as filtration or removal of the particles by mechanical means goes, it is impossible to get the rubber out of it. The slightest addition of acid will bring down the rubber, and the precipitate can be worked together and matted. The outline of the process is roughly this: The rubber is briefly digested with alkali under some pressure and then benzole or other solvent added. These first treatments serve to soften and loosen up the rubber. After the two treating liquids are drawn off or distilled, pure water and steam are all that are used. The rubber actually appears to dissolve in the water, and to give a solution which can be filtered, clarified, and the precipitated matter removed. The net result is such an aqueous solution as we have here, from which the rubber can be removed and recovered if desired. How far the process will be valuable commercially depends a great deal on circumstances that are not yet clear. One of the difficulties is the tendency occasionally to harden up. It seems interesting, and I wanted to bring it up chiefly from its academic interest. The solution of the rubber takes it back almost to the condition of the juice of the tree. The aqueous solution behaves in very much the same way as the juice from the rubber plant. By standing it will separate out. Upon treatment with the same chemicals it will separate out in the same way, and give very much the same kind of black, soft and extremely resilient rubber which is obtained from the original rubber plant. The technical value, of course, is largely dependent upon how permanent the solution will be. Some samples have been permanent for four or five years and apparently have retained

all their original properties. Others have appeared to go to pieces, as in the case of the present sample. These points have not yet been threshed out, and it was taken up only to bring in one more feature of an industry of which Dr. Sharples has given us such a complete résumé.

ON THE PERMANENCE AND ACIDITY OF HYDROGEN PEROXIDE SOLUTIONS

By LAUNCELOT W. ANDREWS

Read at the Philadelphia Meeting, Dec. 10, 1909

Commercial solutions of hydrogen peroxide may be divided into two classes, according to whether they are intended for technical or for medicinal uses. These grades differ chiefly in the amount and character of the dissolved solids, in the keeping quality and in the degree of acidity. For the purpose of forming a judgment, all the points named should be covered by suitable tests, but the last two seem to demand special comment and to their consideration the present paper will be restricted.

Acidity

The acidity of hydrogen peroxide solutions of American manufacture is usually due to one or more of the following acids:

1. Sulphuric acid;
2. Phosphoric acid (or acid phosphates);
3. Hydrochloric acid;
4. Fluosilicic acid;
5. Carbonic acid;
6. Organic acids (sulphonic acids, etc.).

The degree of acidity is of importance from a medicinal standpoint, and, accordingly, the United States Pharmacopœia has established a standard limiting the amount of acid which is permissible in peroxide sold for medicinal applications.

Now, for several reasons, the determination of "degree of acidity" is not so simple a matter as it appears. In the first place, the term "acidity" is ambiguous and the conception on which it is based is indefinite. To make this clear, let us suppose that two samples of hydrogen peroxide are presented for comparison,

both of which require 5 cc. of tenth normal alkali to neutralize* the acid contained in 50 cc. of the solution. Suppose, further, that the acid in one sample is hydrochloric, in the other, a weak acid, as acetic or carbonic. Shall we say that the "degree of acidity" is the same in both, or not? The sample containing the "weak" acid will be far less sour to the taste and far less irritating to a raw surface. Physiologically, they are not at all equivalent. In a word, we must distinguish between the *intensity* and the *amount* of *acidity*.

In practice, the relation of the amount to the intensity of acidity can be roughly judged by titrating twice with two properly selected indicators, for example, phenolphthalein and methyl orange or phenolphthalein and nitrophenol. The latter is more sensitive but has the disadvantage of giving a vague end-point when phosphoric acid or acetic acid is present. In each case, the consumption of alkali when phenolphalein is employed represents the amount of acidity, whereas the consumption when methyl orange is used may be taken as a measure of its intensity.

To adduce an actual example; two lots of peroxide from different manufacturers were examined with the following results: Sample A. 50 cc. required 2.85 cc. with pht., 1.55 with nitrophenol. Sample B. 50 cc. required 2.50 cc. with pht., 2.25 with nitrophenol.

It is clear that sample A has a greater amount of acidity than B, but has less intensity. Physiologically it is milder and, hence, preferable.

These considerations lead, obviously, to the conclusion that phenolphthalein is, from the pharmacognostic standpoint, less well adapted than is an indicator of the methyl orange class, to the determination of the acidity of hydrogen peroxide solutions, if the choice be limited to a single indicator.

In addition to the phenomena discussed in the preceding paragraphs, the seemingly simple affair of the determination of acidity in hydrogen peroxide solutions is further complicated by the oxidizing action of the peroxide on the organic matter, a reaction which gives rise to acids not originally present. The organic matter is furnished by the "preservative" † and by the indicator itself. The amount of acid so produced may many times exceed that originally present in the unaltered liquid, and it becomes a

* The use of phenolphthalein as indicator is presupposed.

† Usually (as is well known), but not always, acetanilide or phenacetine.

question of importance to settle the conditions which reduce these sources of error to a minimum.

The U. S. Pharmacopœia (Ed. VIII, 55) prescribes the following process for determining the acidity of hydrogen peroxide solution:

> "If to 25 cc. of the solution, 5 cc. of tenth normal potassium hydroxide V.S. be added, and the mixture be evaporated to about 10 cc., and 3 drops of phenolphthalein T.S. added, not less than 2.5 cc. of tenth normal sulphuric acid V.S. should be required to discharge the red color of the solution after continued boiling (limit of *free acids*)."

What the object of this procedure may be is not known to me. If the preliminary evaporation be intended to destroy the peroxide, it falls far short indeed of accomplishing that end. Its effect is, really, to oxidize a part of the organic preservative (present in all samples of commercial peroxide for medicinal purposes which have good keeping qualities) with the formation of alkali salts of organic acids and sometimes of alkali nitrate. In the second boiling, subsequent to the addition of the phenolphthalein, the residual peroxide extends its oxidizing action to this also, sometimes entirely destroying it, and converting it into products of acidic properties. That is to say, at both stages of the process acids are formed by unforeseen reactions, a fact which tends to invalidate the results obtained.

The oxidation of the preservative, which takes place rapidly in hot alkaline solution, occurs slowly at ordinary temperatures and without addition of alkali, so that samples which have been kept one or two years exhibit sometimes more than double the acidity which they had when fresh. The fact that brands loudly heralded on the market as containing no preservative show a similar increase of acidity throws light on the validity of those claims.

If the titration be carried out in a cold solution and as rapidly as possible, using nitrophenol or methyl orange as indicator, perfectly accurate results may be obtained, and, if phenolphthalein be employed with the same precautions, the results are also trustworthy, being not more than 0.10 cc. too high. The following experiments record the evidence on which these several assertions rest.

Experimental

1. Perhydrol (30 per cent), free from acids and from non-volatile residue, was diluted with the purest distilled water to make a solution which contained 3.41 per cent of H_2O_2. This solution was used for experiments 1, 2, 3, 4, 5.

Twenty-five cc. of this liquid was treated with three drops (0.20 cc.) of phenolphthalein solution (1 per cent) and titrated with fiftieth normal potassium hydroxide. Of the latter, 0.20 cc. were required to produce a red coloration.

2. To 25 cc. of the perhydrol solution 1.00 cc. of tenth normal KOH and 2 cc. of phenolphthalein solution were added and the mixture at once titrated with tenth normal hydrochloric acid, of which 1.03 cc. were required.

Then 5 cc. more of the KOH were added and the mixture heated in the steam bath for five minutes. The color became very pale and only 0.12 cc. of the standard acid was required to titrate back.

Of the alkali, 10 cc. more were added and 2 cc. phenolphthalein and the whole heated as before, but for ten minutes. The color was entirely discharged. Two cc. of phenolphthalein were added, which turned the liquid red. The color was discharged by addition of 0.65 cc. of tenth normal acid. Added, 5 cc. more of the alkali and heated as before for 5 minutes. The color was still red and 2.00 cc. of acid were needed to neutralize.

This experiment demonstrates that phenolphthalein is oxidized by alkaline peroxide to colorless products and that the acids formed from the (excessive amount of) indicator used sufficed to neutralize 17.2 cc. of tenth normal alkali. The conclusion can also be drawn, that the normal amount of indicator solution, 0.2 cc., is capable of furnishing acid to neutralize 0.65 cc. of tenth normal alkali, a deduction confirmed by the next experiment.

3. Taken, 25 cc. of the perhydrol solution, which was boiled down to about 10 cc. Three drops of phenolphthalein solution were added and the boiling continued. The solution was then very pale red. 4.32 cc. of the acid were required for neutralization. Alkali consumed = 0.68 cc.

This is, in effect, a method of titrating the phenolphthalein.

4. Materials and conditions the same as in number 3, except that the liquid was boiled down faster, four minutes elapsing before the volume was reduced to 10 cc. After one and a half minutes

boiling, subsequent to the addition of the 3 drops phenolphthalein the solution became colorless, but the ebullition was continued three and one-half minutes more. Then, 3 more drops of indicator were added to the hot solution. After cooling, 3.45 cc. of tenth normal acid were required to neutralize. It appears that more vigorous boiling in this case produced more acid than before, probably because the time was shorter and, hence, less of the peroxide was decomposed by the heat.

5. This and the following experiments were on two lots of commercial medicinal peroxide made by different manufacturers, marked "A" and "B."

Taken, 50 cc. peroxide "A." Titrated cold and rapidly with 3 drops of phenolphthalein. Required: 2.51 cc. tenth normal HCl.

6. Taken, 50 cc. of peroxide "A," to which 15 cc. of tenth normal alkali and a small pinch of phenolphthalein powder were added. Boiled gently for ten minutes. There was hardly any color left. Addition of more phenolphthalein powder greatly enhanced the color, showing that most of the first portion had been oxidized. To neutralize, 0.12 cc. of standard acid was needed. This experiment demonstrates that the acid formed is not derived from the oxidation of the alcohol contained in the phenolphthalein solution. In fact, another experiment, not recorded here, shows that alcohol does not give rise to an appreciable amount of acid under the conditions.

7. Taken, 50 cc. of peroxide "A." Heated in steam bath five minutes, then boiled one minute, and cooled. Titrated when quite cold. Required, 3.25 cc. alkali. The end point was indefinite and the color faded rapidly.

8. Boiled 50 cc. of peroxide "A" for thirteen minutes. When cold, added 3 drops of phenolphthalein. Required: 3.10 cc. standard alkali. End point indistinct. This and the preceding experiment demonstrate that acid is produced by the mere heating of this brand of peroxide, without previous addition of alkali; whether as a result of hydrolysis alone or of oxidation does not appear.

9. Boiled 50 cc. of peroxide "A" for twenty minutes with 25 cc. of tenth normal KOH and a pinch of phenolphthalein powder. At the end of ten minutes the color had become very pale and did not change much afterward. To neutralize, 0.08 cc. of standard acid was requisite. Total alkali consumed = 24.92 cc. There is

no doubt that more alkali would have been neutralized if more had been present. This and several of the other experiments show that the oxidation of the phenolphthalein becomes very slow when the solution is neutral or only faintly alkaline.

10. Titrated 50 cc. of peroxide "A," using an aqueous solution of *p*-nitrophenol as indicator. Required: 0.70 cc. of tenth normal acid for the first perceptible yellow tint and 1.55 cc. for a deep yellow. This wide range is characteristic of samples in which the acidity is largely due to phosphoric acid and acid phosphates. On boiling the solution with more nitrophenol, a permanent yellow color was produced, not removable on acidification.

11. Titrated 50 cc. of peroxide "B" with 3 drops of phenolphthalein. Required: 2.85 cc. of tenth mormal alkali.

12. Boiled 50 cc. of peroxide "B" with 3 drops of phenolphthalein solution and 5 cc. of tenth normal KOH for five minutes. The liquid lost all color in less than one minute, and remained perfectly white. Addition of 3 drops more of the indicator to the cold solution produced no change and 0.90 cc. of the standard alkali were required to neutralize. Total alkali consumed, 5.90 cc. The color change was much sharper than in the case of peroxide "A." Here, if we allow a correction of 0.65 cc. of alkali for the acid produced from the indicator, we have 2.40 cc. required for the acids formed by the decomposition of the acetanilide, which was shown by analysis to be present in the sample.

13. In this experiment (as elsewhere) the time of boiling recorded included the entire time from the beginning of heating. About ninety seconds elapsed before ebullition commenced. Boiled 50 cc. of peroxide "B" for ten minutes with 10 cc. of tenth normal KOH. Chilled quickly, then added 3 drops of phenolphthalein. Required: 0.18 cc. of acid, whence, 9.82 cc. of the alkali were consumed.

Ten cc. more of the alkali were then added and the liquid boiled for ten minutes, when it was cooled and titrated as usual after the necessary addition of the usual amount of phenolphthalein. Required: 0.90 cc. of standard acid. Consumed on the second boiling 9.10 cc. tenth normal alkali, or in all, 18.90 cc. There can be no doubt that more boiling would have resulted in the formation of still more acid.

The observations recorded above demonstrate that the pharmacopœia method for the determination of the acidity of hydrogen

peroxide solutions, which is now the legally prescribed method for the United States, is so seriously affected by sources of error, that it is no exaggeration to say the results stand in no necessary relation to the amount of acid actually present.

The data given permit the following conclusions to be drawn:

A. In determining the acidity of hydrogen peroxide, the solution must not be heated, either before or after the addition of the indicator.

B. The results obtained by titration with phenolphthalein and decinormal alkali in the cold, and avoiding undue delay, are correct and there is no object in trying to decompose the peroxide in a preliminary operation.

C. While the results obtained by the use of phenolphthalein are, with proper precautions, correct, they are misleading when used as a basis for a judgment of the physiological acidity, that is to say of the intensity factor of the acidity.

D. A better measure of the physiological acidity can be based on the use of an indicator of the methyl orange class. This change would involve an alteration in the limit of acidity as expressed by the volume of tenth normal alkali consumed. A suitable limit would then be about 1.7 to 2.0 cc. for 50 cc. of the solution.

E. Since the presence of carbon dioxide in solutions of hydrogen peroxide is without significance for its therapeutic applications, if the titration by phenolphthalein is retained, either by itself or in conjunction with an indicator of the methyl orange class, it should be provided that the carbon dioxide shall be removed from the solution by a current of air, before titration.

Permanence

The permanence or keeping quality of the various hydrogen peroxides on the market varies greatly and is a characteristic of high importance to the consumer and to the manufacturer alike. The conditions influencing the permanence of this substance are so numerous and the presence in the solution of catalyzers which impair permanence is so difficult to establish by chemical analysis, no matter to what point it may be refined, that one is driven to seek a more direct method. A good solution, properly treated

with any one of a number of anticatalyzers, and successfully packed, should keep one or even two years without very serious deterioration. It is, of course, impossible to apply this test, except as an ultimate criterion by which to judge the value of a practical but empirical method which can be carried out quickly.

A determination of the loss of strength at an elevated temperature suggests itself as a possible solution of the problem. While it is not to be expected that, for different samples of peroxide, there will be found a fixed relation between the rate of decomposition at two widely separated temperatures, still, it is intrinsically probable that the ratio of the rates will approximate to constancy sufficiently to enable a judgment to be formed of the permanence at ordinary temperatures from that observed at a fixed higher temperature, say, at 100°.

Experience has shown that such is the fact and that specimens of bad keeping quality may be distinguished from those of good by their rapid loss of strength when heated to 100° for thirty minutes. To secure trustworthy results, it is simply necessary to heat in a uniform manner and to guard against loss of water by evaporation and against accidental contamination.

The author has used this method in the examination of more than a thousand samples, in the following form. The apparatus (Fig. 1) consists of a fusible metal bath, contained in an enameled iron dish 25 cm. in diameter, in which are placed four Jena glass Kjeldahl flasks of 500 cc. capacity. The bath is heated by one Bunsen burner. Each flask carries a cork stopper, to which is fitted a reflux Liebig condenser, 50 cm. long. The inner tube of the latter is one-half inch in diameter and is made of aluminium. This arrangement permits four samples to be tested simultaneously. One hundred cc. of peroxide is placed in each flask and the flasks are all immersed in the melted metal to about the same depth and so that the meniscus of the liquid within is above the level of the metal without. Boiling begins in about two minutes and is vigorously maintained for thirty minutes. It is well to place a loose plug of absorbent cotton in the upper end of each condenser tube to prevent the ingress of dust or insects. A modification of this apparatus arranged for six simultaneous tests is shown in the figure. The fusible metal bath is contained in a cast-iron trough heated by steam pipes to 125–135°.

A portion of the sample (2 cc.) is titrated in the ordinary way with tenth normal permanganate before and after the boiling. With samples of first-class quality the loss of titre on boiling is about 0.5 cc., equivalent to 3 per cent of the peroxide originally present. Sometimes only 1 per cent is lost. A deterioration of 6 per cent does not, however, indicate that the sample is defective. A sample of doubtful or bad keeping quality will lose from 10 to 50 per cent or more under the test. Very old samples naturally

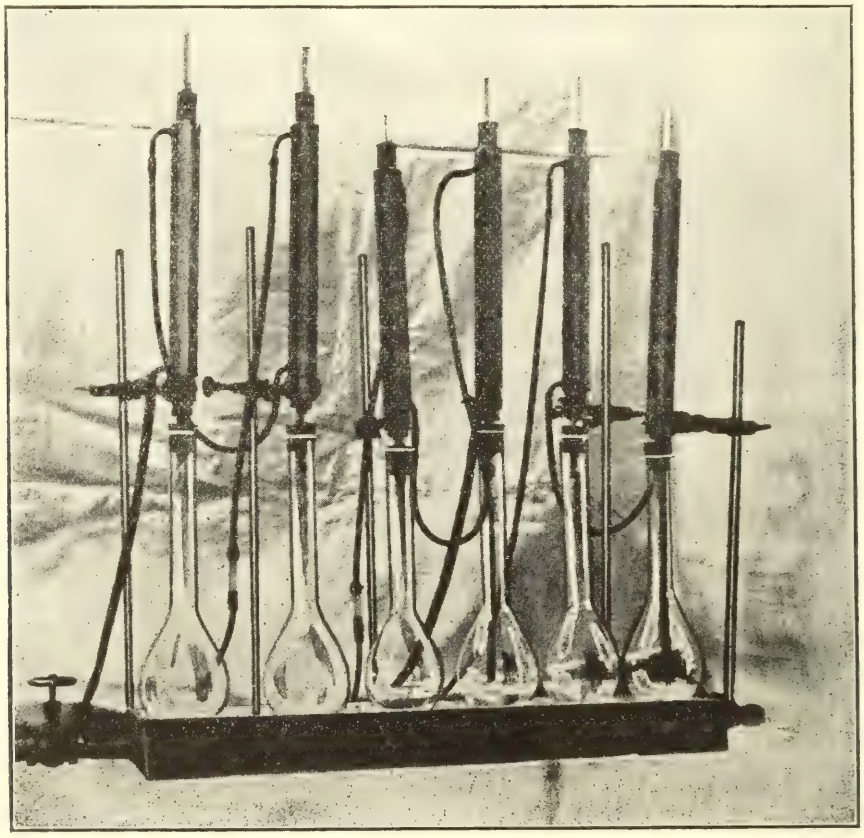


FIG. 1.

lose more than fresh ones. If the percentage loss in thirty minutes under the boiling test be multiplied by a coefficient which varies between 2 and 3, the product represents approximately the loss in one year under average conditions of light and at atmospheric temperatures indoors. The temperature coefficient of the reaction is greater than for most chemical changes, approximately trebling for every 10° C. of temperature increase. The permanence of the solution increases with the intensity factor of

the acidity only when the acidity is low. A maximum is soon reached, beyond which further increase of acidity impairs the keeping quality. Consequently, in the neighborhood of the optimum acidity, the permanence is but little affected by moderate changes in the amount of acid. This relation holds for pure perhydrol as well as the commercial article containing a preservative. Hence, it cannot be ascribed, as might be surmised, to an hydrolytic decomposition of the preservative under the influence of the acid.

Research Laboratory of the Mallinckrodt Chemical Works, St. Louis.

COMMERCIAL EXTRACTION OF GREASE AND OILS

By WM. M. BOOTH, Syracuse, N. Y.

Read at the Philadelphia Meeting, Dec. 10, 1909

A certain percentage of fat is found in nearly all animal and plant structures. In many instances nature provides a special tissue or reservoir for storing energy in this way, in others fat is secreted to serve as a lubricant for the tissues themselves.

The extraction of animal and vegetable oils has been general among all races and from very early times. In its simplest forms, the fat-carrying globule has been separated from its enveloping tissue by heat and pressure. Whale blubber, fish-oil and many of the oils of the tropics yield to this treatment. The modern development of the art has been toward high temperatures and extreme pressure. Steam is well adapted to the first form of treatment, the hydraulic press to the latter. In some instances centrifugal machines are used to good advantage either with or without heat.

Traffic in fat-bearing materials has resulted in a demand for the exact estimation of the fat itself. The Soxhlet apparatus and its variations are universally used by practical chemists. In this way appropriate solvents have been applied where found most available. Wide variations exist between the best results obtained by heat and pressure and those found possible with solvents. Indeed from 5 per cent to 20 per cent of the fat remains in the cake or scrap unless a solvent is used for extraction. With linseed oil, cottonseed oil, or corn oil the use of the cake for feeding purposes does not require close separation. Where the pressings are thrown away or burned, a large percentage of residual oil is wasted. Hence, engineers have applied variations of the Soxhlet extractor to the needs of the manufacturer, replacing the glass cylinders and tubes with metallic tanks and pipes, sometimes on an enormous scale. Extraction tanks are now in use capable of accommodating 10,000 gallons of naphtha at one charge. Nearly three hundred

patents have been granted for machines and apparatus dealing with extraction amd kindred processes.

A practical solvent for fat extraction must fulfill certain conditions. It must be inexpensive and must be easily obtained in large quantities. It should be capable of being distilled by steam at or under 60 pounds pressure, which requires a fluid of low boiling-point. Many fats decompose when heated. As their acids are corrosive, the metal apparatus itself is rapidly destroyed. A suitable extractive material must be capable of complete separation from the fat extracted, and finally it must not leave taste or odor in the fat itself. An additional advantage of a low boiling-point solvent is economy in heat, fewer B.T.U. being required. Other conditions being approximately equal, a solvent should be non-combustible.

The fluids ordinarily used for fat extraction are naphtha, benzol, carbon disulphide, chloroform, ether and carbon tetrachloride. We have arranged a table showing the cost of the above solvents per pound, also per gallon:

Solvent.	Cost per Pound.	Cost per Gal.
Commercial chloroform	$0.25	$3.11
Carbon tetrachloride	0.08	1.07
Sulphuric ether	0.32	1.05
Carbon disulphide	0.04	0.42
Gasoline	0.024	0.14
Benzol (90 per cent)	0.034	0.25

Chloroform and carbon tetrachloride are non-combustible under ordinary circumstances. Carbon disulphide ignites below red heat. Gasoline is not ignited except by the naked flame or electricity, and for practical purposes on a large scale, this solvent is very generally used, as it is also relatively inexpensive.

We have tabulated some of the physical properties of these solvents:

Solvents.	Density at 15° C.	Boils at Degrees Cent.	Boils at Degrees F.
Ether	0.73	34–36	97.2
Carbon disulphide	1.27	46–47	114.8
Chloroform	1.49	60–62	140.0
Gasoline	0.71	80–160	144–320
Carbon tetrachloride	1.60	77	168.8
Benzol	0.88	80.5	177.0

Later we expect to determine the British thermal units required for the evaporation of each of the above.

To anyone unacquainted with the solvent action of these materials, the amount of fat capable of being absorbed is surprising. As examples of cheap fats which are in a large number of instances thrown away, we have selected wool and garbage grease, both of which are now extracted in large quantities.

The following table shows the percentage of grease dissolved:

Solvent Used.	Grease Used.	Density of Solution.	Percentage of Grease Dissolved.
Chloroform	Garbage G.	1.199	36.27
Chloroform	Dégras	1.211	31.76
Carbon tetrachloride	Garbage G.	1.190	44.18
Carbon tetrachloride	Dégras	1.303	33.34
Ether	Garbage G.	0.847	49.00
Ether	Dégras	0.832	43.00
Carbon disulphide	Garbage G.	1.090	43.60
Carbon disulphide	Dégras	1.1480	33.50
Gasoline	Garbage G.	0.832	35.70
Gasoline	Dégras	0.795	32.60
Kerosene	Garbage G.	0.8465	44.09
Kerosene	Dégras	0.8461	38.13
Benzol	Garbage G.	0.898	54.32
Benzol	Dégras	0.876	47.56

These tables indicate that the cheapest low boiling-point solvent is gasoline or naphtha. We have purchased samples in the open market and present a curve (Fig. 1), showing the percentage distilled at different temperatures. This table contains a belt within which grease is readily extracted and recovered from many substances including wool, dry garbage and leather.

We purchased a sample of gasoline from a drug store to get the boiling-curve. It began to boil at 80° C. and most of it distilled off at 150° C. In connection with the leather and the garbage business, particularly in connection with the leather industry, it has been our experience that a gasoline which boils above 120° C. is quite difficult to separate from the dissolved grease, so that we have made what may be called a "Degreasing Belt," which includes commercial naphtha, boiling between 80° and 120° C. (Fig. 2). There are two reasons for the use of this belt; first, the increased amount of heat required to raise the gasoline through the distilling apparatus and send it through the coils if it boils above 120° C.; second, the difficulty of separating a high boiling-point gasoline from the grease without "cracking" the grease. Kerosene has such an interesting solvent action upon both greases and

"dégras," that we also made a curve of its boiling-points. The curve concludes with about 70 per cent of distilled matter.

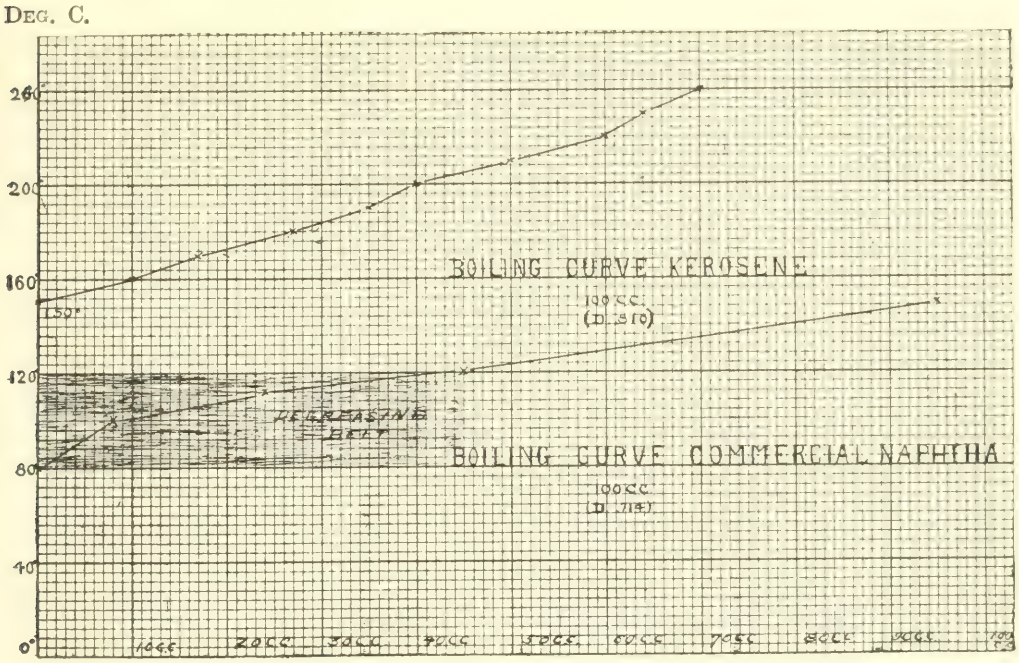


FIG. 1.

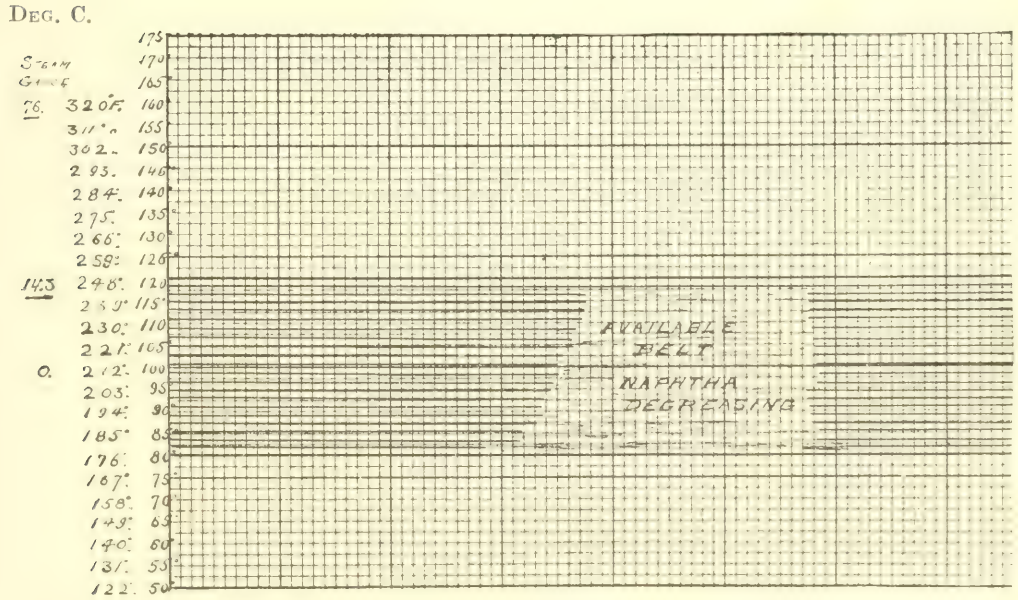


FIG. 2.

Kerosene starts where naphtha leaves off, and distills up to 240° C. The remainder was very difficult to evaporate indeed, so that

while kerosene is a good solvent it is totally useless for the extraction of either garbage grease, or the grease from leather or wool.

For practical purposes, ordinary steel construction is satisfactory for building extracting machinery, and a heating coil made of a good quality of iron will withstand the corrosive action of the fats extracted. Our own experience in this particular covers a period of two years with a machine in constant use.

One of the simplest and most efficient forms of extractor con-

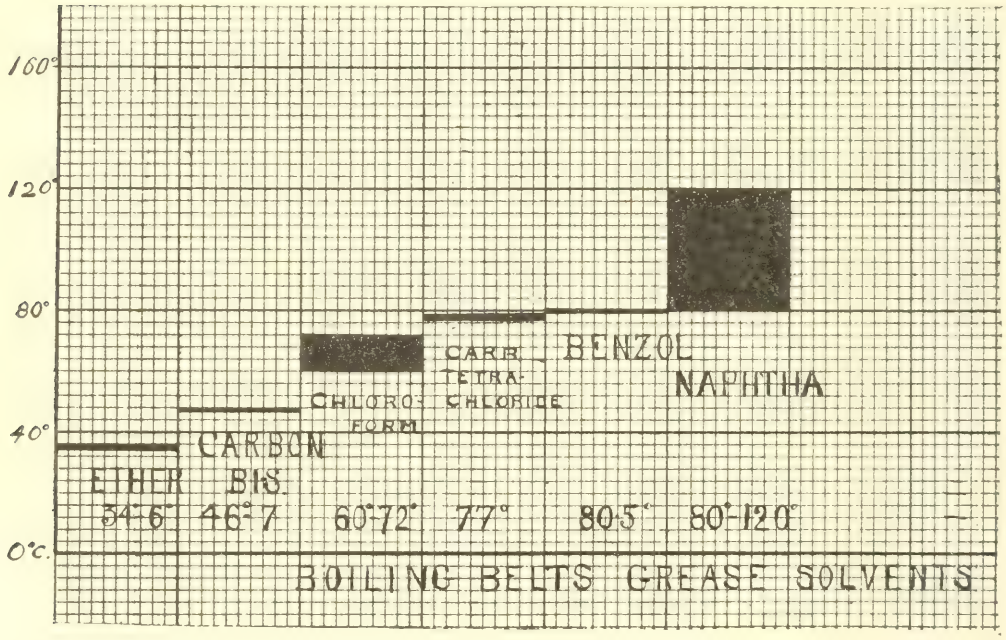
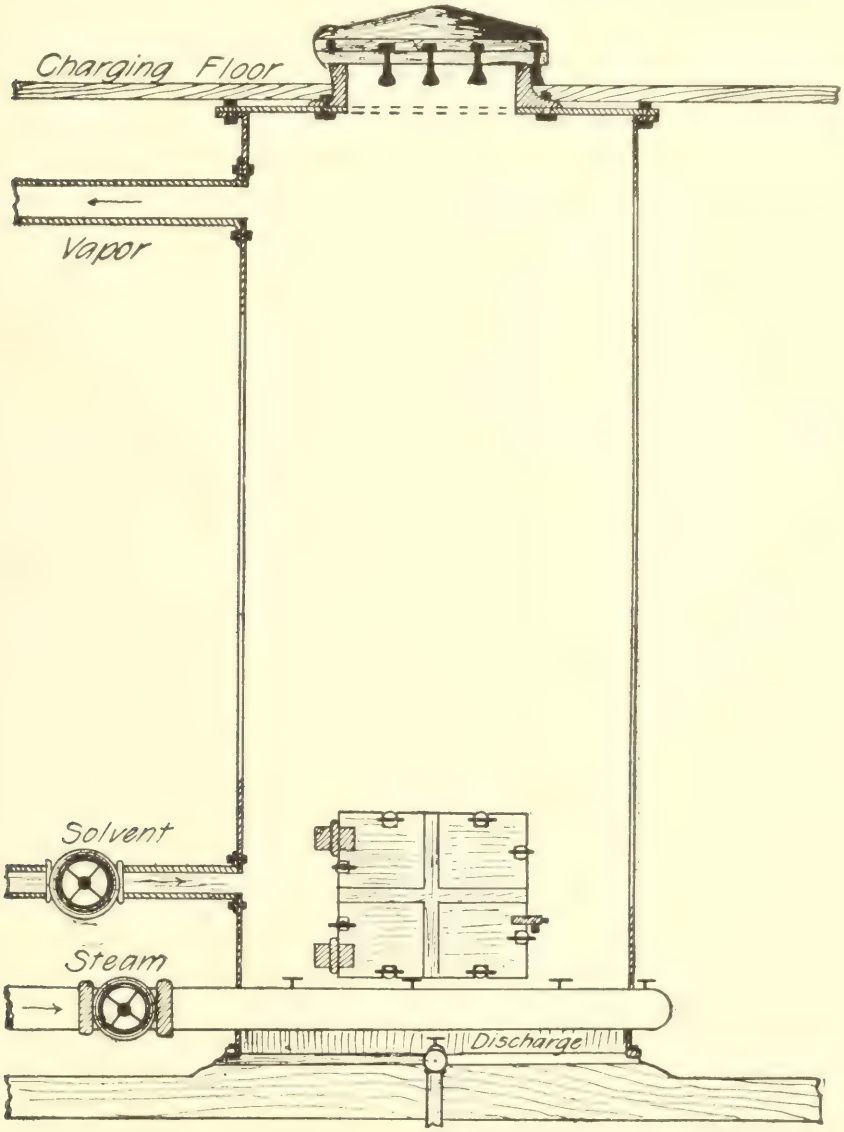


FIG. 3.—Shows the relative boiling-points or boiling belts of the more common solvents.

sists of a closed cylindrical container within which the material to be extracted is placed, usually through a large manhole in the top (Fig. 4). Suitable metal strainers are provided to prevent the naphtha exits from choking. We have not been able to extract grease from leather or dry garbage simply with the naphtha vapor. The cold or slightly warmed solvent is introduced in such quantity as to completely envelop the mass. The solvent flows into the apparatus either by gravity supply or is pumped in with a metal ring pump. A steam coil is sometimes used to increase the extractive power of the solvent. When the process is complete, the liquid is run off into a distilling apparatus where the grease is separated (Fig. 5). The naphtha is evaporated and passed through

cooling coils while the grease flows downward into large tanks. Very interesting apparatus has been developed to effect complete evaporation and separation. When the product is ready for mar-



EXTRACTOR
COARSE MATERIAL
Scale ½=1'

FIG. 4.

ket, the storage tank is warmed by steam coils, air is admitted through the top of the tank, while the grease is forced out through the bottom into tank cars.

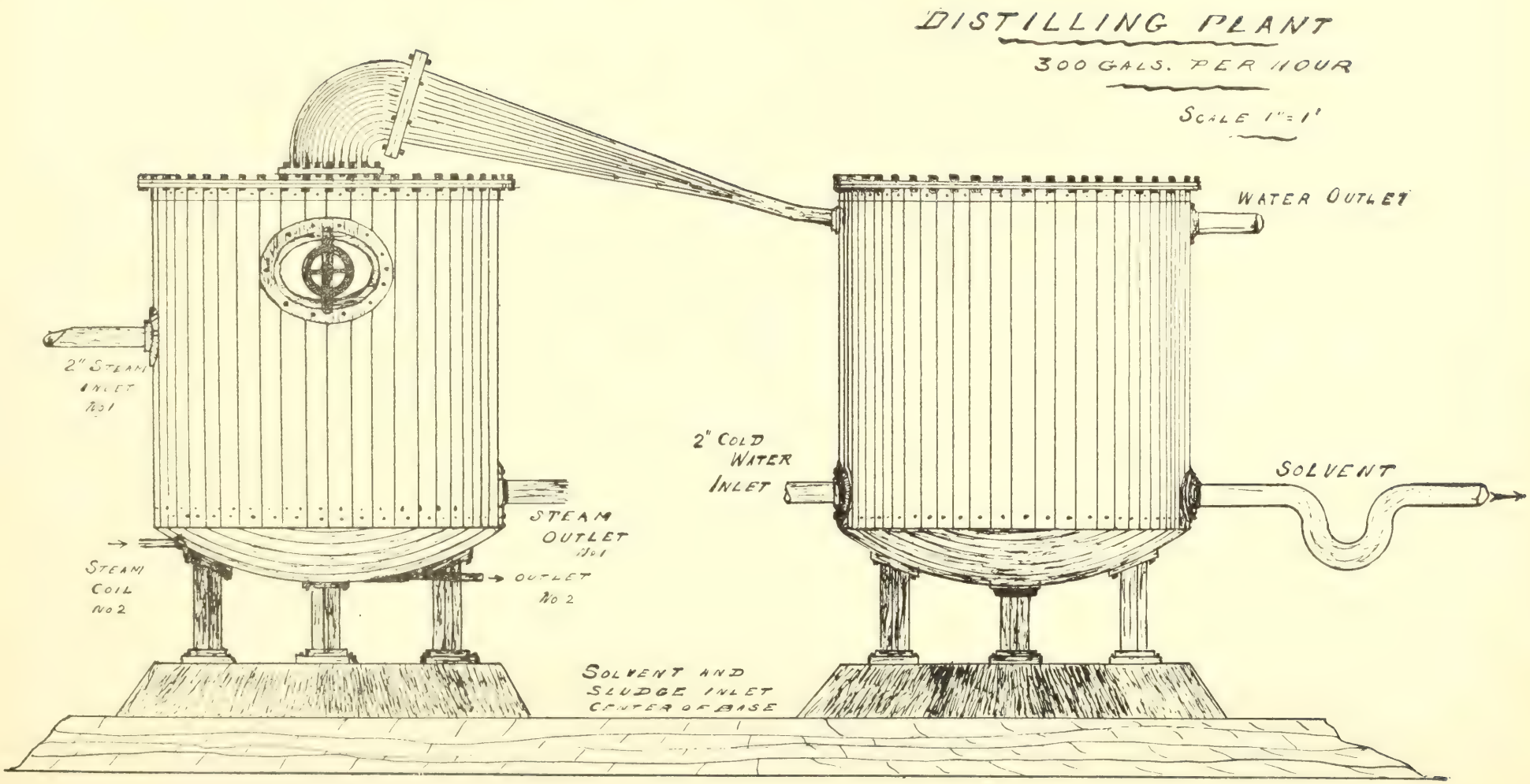

DISTILLING PLANT
300 GALS. PER HOUR
SCALE 1"=1'
WATER OUTLET
2" STEAM INLET No 1
2" COLD WATER INLET
SOLVENT
STEAM OUTLET No 1
STEAM COIL No 2
OUTLET No 2
SOLVENT AND SLUDGE INLET CENTER OF BASE

FIG. 5.

The naphtha extraction is made more complete by introducing live steam and separating the resulting naphtha and water at their dividing line, a point which is easily determined through a glass gauge at the side of the apparatus. Small pieces of white paper dipped into the naphtha and dried, almost immediately prove the presence or absence of grease. By this process, from 80 per cent to 90 per cent of the fat in low-grade materials can be cheaply recovered. This applies to fish waste, slaughter house sweepings, garbage and tankage. The material to be extracted must not contain more than 2 per cent or 3 per cent of moisture, otherwise the solvent action is superficial. When steam is added to drive off residual naphtha, the solid matter takes up about 10 per cent of water which must be again dried out.

We made tests to determine the percentage of grease entrained by naphtha when the mixture was distilled. The apparatus employed had but recently been installed. The distilling and cooling tanks were each 5 feet in diameter and 5 feet in height (Fig. 5). The heating coil was 2 inches in diameter and supplied by steam at 60 pounds pressure. Six and one-half barrels of naphtha were distilled per hour. This was examined for its grease content. The grease found in parts per million of naphtha distilled was as follows:

First barrel	0.560
Second "	0.044
Third "	0.055
Fourth "	0.016

The result obtained in the first instance was attributed to grease in the new coil. Other tests have been made which prove that naphtha can be distilled from grease without (appreciable) entrainment. In the foregoing instance the residue in the distilling apparatus was analyzed and found to contain:

Heavy grease	29%
High boiling naphtha	6
Water	65

When water is present in the still, a small percentage passes over, but separates after an hour or more.

A fat-extraction plant is a very dangerous piece of apparatus unless handled with extreme caution. All closed containers should be provided with safety valves or plugs to prevent explosion

TEMPERATURES * CORRESPONDING TO VARIOUS STEAM PRESSURES

Pounds Pressure Per Sq. In. Absolute.	Steam Gauge Pressure. Pounds.†	Temperature, Degrees C.	Temperature, Degrees F.	Pounds Pressure Per Sq In. Absolute.	Steam Gauge Pressure. Pounds. †	Temperature, Degrees C.	Temperature, Degrees F.
14.7	0.00	100.00	212.00	67	52.30	148.80	299.85
15	0.30	100.57	213.04	68	53.30	149.35	300.84
16	1.30	102.40	216.33	69	54.30	149.89	301.81
17	2.30	104.13	219.45	70	55.30	150.42	302.77
18	3.30	105.77	222.40	71	56.30	150.95	303.72
19	4.30	107.36	225.25	72	57.30	151.49	304.69
20	5.30	108.86	227.95	73	58.30	152.00	305.60
21	6.30	110.33	230.60	74	59.30	152.51	306.52
22	7.30	111.72	233.10	75	60.30	153.01	307.42
23	8.30	113.05	235.49	76	61.30	153.51	308.32
24	9.30	114.34	237.81	77	62.30	154.01	309.22
25	10.30	115.59	240.07	78	63.30	154.50	310.11
26	11.30	116.80	242.24	79	64.30	154.99	310.99
27	12.30	117.95	244.32	80	65.30	155.47	311.86
28	13.30	119.08	246.35	81	66.30	155.95	312.72
29	14.30	120.18	248.33	82	67.30	156.42	313.57
30	15.30	121.25	250.26	83	68.30	156.91	314.44
31	16.30	122.29	252.13	84	69.30	157.36	315.25
32	17.30	123.32	253.98	85	70.30	157.82	316.08
33	18.30	124.31	255.77	86	71.30	158.27	316.90
34	19.30	125.29	257.52	87	72.30	158.72	317.71
35	20.30	126.23	259.22	88	73.30	159.19	318.55
36	21.30	127.15	260.88	89	74.30	159.61	319.31
37	22.30	128.05	262.50	90	75.30	160.10	320.18
38	23.30	128.93	264.09	91	76.30	160.48	320.88
39	24.30	129.80	265.65	92	77.30	160.92	321.66
40	25.30	130.65	267.17	93	78.30	161.34	322.42
41	26.30	131.47	268.66	94	79.30	161.77	323.18
42	27.30	132.28	270.12	95	80.30	162.19	323.94
43	28.30	133.08	271.55	96	81.30	162.59	324.67
44	29.30	133.86	272.96	97	82.30	163.01	325.43
45	30.30	134.62	274.33	98	83.30	163.42	326.17
46	31.30	135.37	275.68	99	84.30	163.83	326.90
47	32.30	136.11	277.01	100	85.30	164.23	327.63
48	33.30	136.84	278.32	101	86.30	164.63	328.35
49	34.30	137.56	279.62	102	87.30	165.03	329.07
50	35.30	138.27	280.89	103	88.30	165.43	329.78
51	36.30	138.96	282.14	104	89.30	165.82	330.48
52	37.30	139.66	283.39	105	90.30	166.21	331.18
53	38.30	140.32	284.58	106	91.30	166.59	331.87
54	39.30	140.97	285.76	107	92.30	166.97	332.56
55	40.30	141.64	286.96	108	93.30	167.35	333.24
56	41.30	142.27	288.09	109	94.30	167.73	333.92
57	42.30	142.91	289.24	110	95.30	168.10	334.59
58	43.30	143.53	290.37	115	100.30	169.93	337.80
59	44.30	144.15	291.48	120	105.30	171.66	341.00
60	45.30	144.76	292.58	125	110.30	173.33	344.00
61	46.30	145.36	293.66	130	115.30	175.05	347.10
62	47.30	145.96	294.73	135	120.30	176.66	350.00
63	48.30	146.54	295.78	140	125.30	178.22	352.80
64	49.30	147.13	296.82	145	130.30	179.77	355.60
65	50.30	147.68	297.84	150	135.30	181.33	358.40
66	51.30	148.25	298.85				

* Data based on Nystrom's Tables, 15th Edit., page 400.
† Varies with altitude and atmospheric pressure. Usually assumed to be 14.7 pounds per square inch at sea level.

from pressure. Smoking should be absolutely prohibited even in the region of the plant. Electric lights only should be used.

We have made experiments with fiber carrying 10 per cent mineral oil, none of which could be extracted by extreme pressure, but nearly all of which was recovered with naphtha. Dry grape seeds would yield but a fraction of 1 per cent of oil when heated and pressed. From these naphtha extracted 10 per cent of an edible oil.

We call the attention of the members of the Institute to the extraction of low-priced oils and greases, because we believe that these represent an actual national asset. Enough garbage is collected in every large city of the United States to average four-tenths of a pound per person daily. Two years ago in the city of Chicago alone, 16,000 pounds of grease were extracted daily from a portion of the garbage. This contains about 4 per cent fat, more than 3 per cent of which can be extracted and marketed. The residual mass is worth from $7 to $10 per ton as fertilizer. In the city of Cleveland, O., these materials are extracted at a profit, nearly paying for collection throughout the city.

The fuel value of grease is not greater than $5 per ton, while its market value when extracted for soap and lubrication is from $60 to $100.

In a well-organized plant the naphtha loss is 16 gallons per ton of grease extracted, costing about $2.50.

The following tables will also be found useful: "Action of Oils on Metals." Oil Analysis, by Augustus H. Gill, p. 114. "Melting Point of Fatty Acids." Ibid. p. 145.

Discussion

Mr. E. Hart:

I would like to point out that the specific heat of most of these substances has already been ascertained, and from a consideration of the specific heats, the comparative amounts of steam necessary to distill the solvents can easily be calculated.

Member:

Is there a commercial naphtha on the market which distills between 80° and 120°? There seems to be some difficulty to get it to distill between these limits. Most of it distills up to 150°.

Mr. Booth:

We are particular that they shall send us a certain product. If they do not we cannot separate our grease and our naphtha.

Mr. E. R. Taylor:

At Wath near Sheffield, England, I visited last summer the works of Charles Stanley & Sons, who use very considerable quantities of carbon disulphide for extracting fats, and they give that body a preference over others for their particular work, especially for getting out a very fine and pure stearic acid, and it is a matter of interest to us as Americans, to know that some of that garbage material that they extract comes from our own country. I have made great exertions to get carbon disulphide into the extracting business in America, but, so far, unsuccessfully. I might mention in passing that it was the use of that substance for extractive purposes that first led me into the business of making such a material.

Mr. Dane:

I come from a country (Australia) vitally interested in the wool business, and have had some work in connection with the industry. If you have one pound per head here, there we have at least ten, on account of the tremendous quantity of wool and the small population. The question of saving the dégras is a very vital one there with some of the big ranch owners. One of them at a place called North Yanko shears over one and a half million pounds of wood per year, and as yet has found no satisfactory commercial method of extracting the grease, and when he did extract it he could find no market for it. He had been to France and all around the world, but it was necessary to come to the United States to find it done successfully every day. I entered into communication with him, and told him that it could be done, but there is a drought on there at present, and he said that he was sticking to the old plan, which was to wash, preserve the washings and sell the wool. Thereupon I entered into a little experimental work with a wool-washing concern in Richmond, Australia. I experimented with solvent methods and found that out there the cost of separating the solvent from the material interfered with the commercial practicability, so we entered into experimental work on mechanical separation of the fats, believing that if we could eliminate the solvent question and introduce a mechanical

process we could cheapen the process, and get a product which would cost us very little. We employed partially centrifugal, partially chemical means with very fair results, and I wanted to ask Mr. Booth if such a thing had been done by him, and if so to what extent. If such a thing could be done it would revolutionize the business, and would be of very great interest to me.

Mr. Booth:

I have not used centrifugal force in this respect.

Mr. Sharples:

Centrifugal force was used upwards of forty-five years ago at Pawtucket, R. I. A man was recovering waste cotton that had been used for wiping machinery by putting it through a naphtha-extraction apparatus, recovering his grease, and sending the waste cotton back to the mills for wiping, and also carding it and making it into cotton wadding. The extraction apparatus was a simple tank in which there was a centrifugal basket suspended. It was filled with the waste to be extracted, then naphtha run through it, the extraction apparatus kept in motion, say for five minutes, then the supply of naphtha stopped, and the cotton waste almost perfectly dried by throwing out the naphtha, which was then passed through a still made with shelves so that the naphtha ran on to the top shelf, and as it gradually became heavier passed down to the lower shelves. That process was in use there a number of years, and may be still for all I know.

Pres. Sadtler:

I should like to say in regard to this matter that it will be of great interest to members of the Institute to see practically carried out to-morrow the process of grease extraction. We have full permission to visit a modern plant to-morrow in which raw Australian wool is cleansed by naphtha, afterwards washed, and the fat and the potash salts separately extracted and utilized.

Mr. Dane:

What is done with the ureates? They sometimes form a large percentage, and are very valuable.

Pres. Sadtler:

The first step in the process is the naphtha washing, the second is the displacement of the naphtha in the closed tanks by water,

followed by carbonating action, and the washing goes on supplementary to the naphtha extraction. The process is one that has been elaborated during several years of time, and there are only two places in the United States where it is carried out.

Mr. E. R. Taylor:

The superintendent of Chas. Stanley & Son of Wath told me something very interesting from a chemical point of view. In extracting the waste from wool with bisulphide of carbon, he found that the residues of nitrogenous material left were rendered soluble, so that all that nitrogenous material was available for fertilizer. Now those who are familiar with the work of Cross & Babbin with reference to cellulose in the production of viscose may turn with some interest to this little fact, that wool possibly might be made to undergo transformation of a similar character, but not just like it; and it might be very interesting to follow that out, and find what result would be obtained by carrying out Cross & Babbin's plan with reference to wool instead of cellulose. Horn and nails and that sort or material differ from cellulose in containing nitrogen, and the character of horn is so peculiar that if the qualities of the residue of viscose should have the additional quality of the stiffness and flexibility of horn, it might result in a very valuable product.

GLYCERINE REFINING IN MULTIPLE-EFFECT STILLS

By F. J. WOOD

Read at the Philadelphia Meeting, Dec. 10, 1909

Crude glycerine contains impurities of such a nature that it would be of very little commercial value if it were not possible to purify it by distilling. When the distillation of glycerine was new as an industry, glycerine was sold in such small quantities that a high manufacturing cost did not prevent its sale in the then small field of its usefulness. Its uses being almost wholly medicinal, a high price to a consumer who only used a few drops occasionally, would not be very objectionable; consequently a method of distillation which was very costly or wasteful would not be a commercial impossibility. Under such commercial conditions, such a destructive distilling apparatus as one designed to actually vaporize the glycerine at the temperature of its boiling point, could be profitably employed.

It is not improbable that the first form of apparatus used for distilling glycerine was on the principle of that shown in Fig. 1, which is a direct-flame-heated still connected by piping to a condenser. The manufacturing cost of distilling with this simple apparatus would be too great to permit of its use at the present time. This cost would be due to waste of glycerine by decomposition. The glycerine would vaporize at the temperature of its boiling point in this apparatus. The fuel used per pound of glycerine distilled would be much less than is used in modern practice. It is very much more economical to vaporize the glycerine at a temperature below its boiling point and to use much more fuel, but decompose less glycerine.

One of the earliest types of apparatus used to vaporize glycerine below its boiling point is that shown in Fig. 2.

While this apparatus represents a great advance over that of

Fig. 1, yet there is still much to be done. The jet of steam issuing from the nozzle in the body of glycerine near the bottom of the still causes the glycerine to vaporize below the boiling temperature, but, after the combined steam and glycerine vapors pass through the air-cooled condensers where most of the glycerine will be condensed, it is impossible to prevent some glycerine from passing out into the air along with the steam. Glycerine will not all condense out of steam after the two vapors have once mingled together, so that the only way to recover all the glycerine that has left the still as vapor is to provide means to condense both steam and glycerine, and afterwards evaporate the water out of the glycerine. Fig. 3

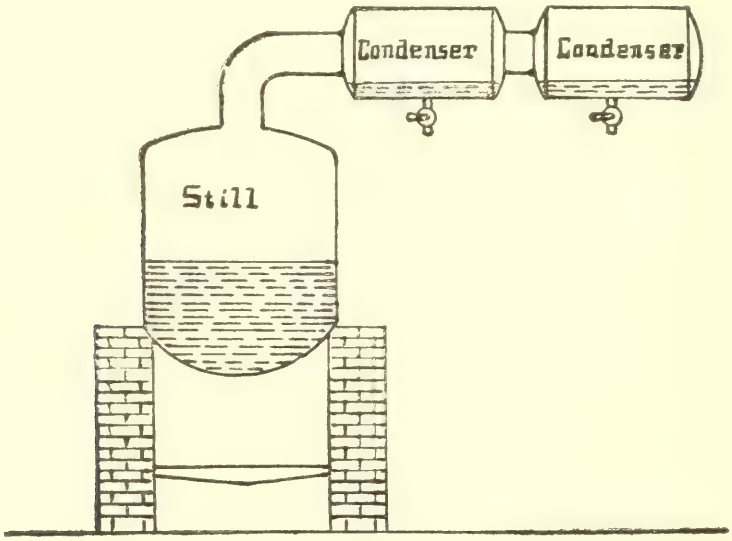


Fig. 1.

shows this next step in advance, which is a cold-water condenser added in series with the air-cooled condensers, and an evaporator to evaporate the water that is condensed along with the glycerine in the cold-water condenser.

When glycerine distillation was in this stage of development, a superheater, as shown in Fig. 3, was added for superheating the steam flow before entering the still. It is remarkable that up to and including this economy in manufacturing, the fuel used per pound of glycerine distilled became greater at each step.

There was still further room for improvement in preventing decomposition by reducing the vaporizing temperature. The vacuum pump shown in Fig. 4 was the means of reducing this temperature. Also, considerable steam was saved by evaporating

the "sweet water" in evaporators arranged as double effects, which will be also seen in this figure. There are many glycerine

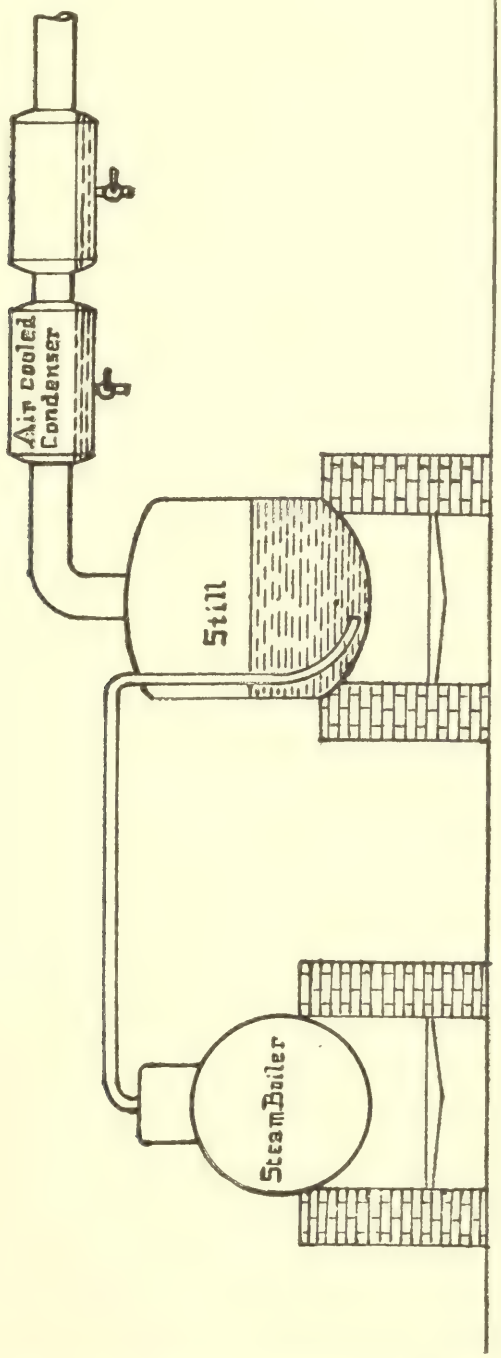


FIG. 2.

distilling plants of the type shown in Fig. 4 operating successfully to-day.

In the Jobbins and Van Ruymbeke apparatus, shown in Fig. 5, the principal and almost the whole difference between it and the

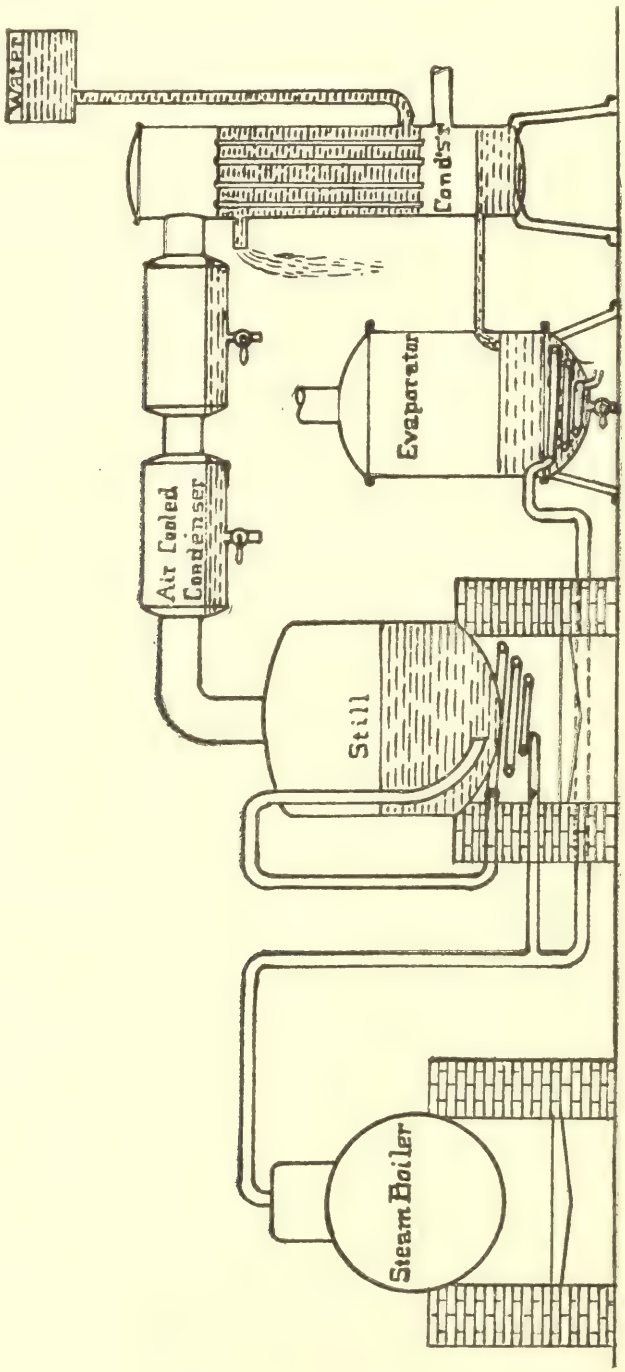


FIG. 3.

earlier type shown in Fig. 4 is in abolishing the direct fire heat under the still and substituting therefor steam-heated coils, both for superheating the flow of steam and for heating the body of

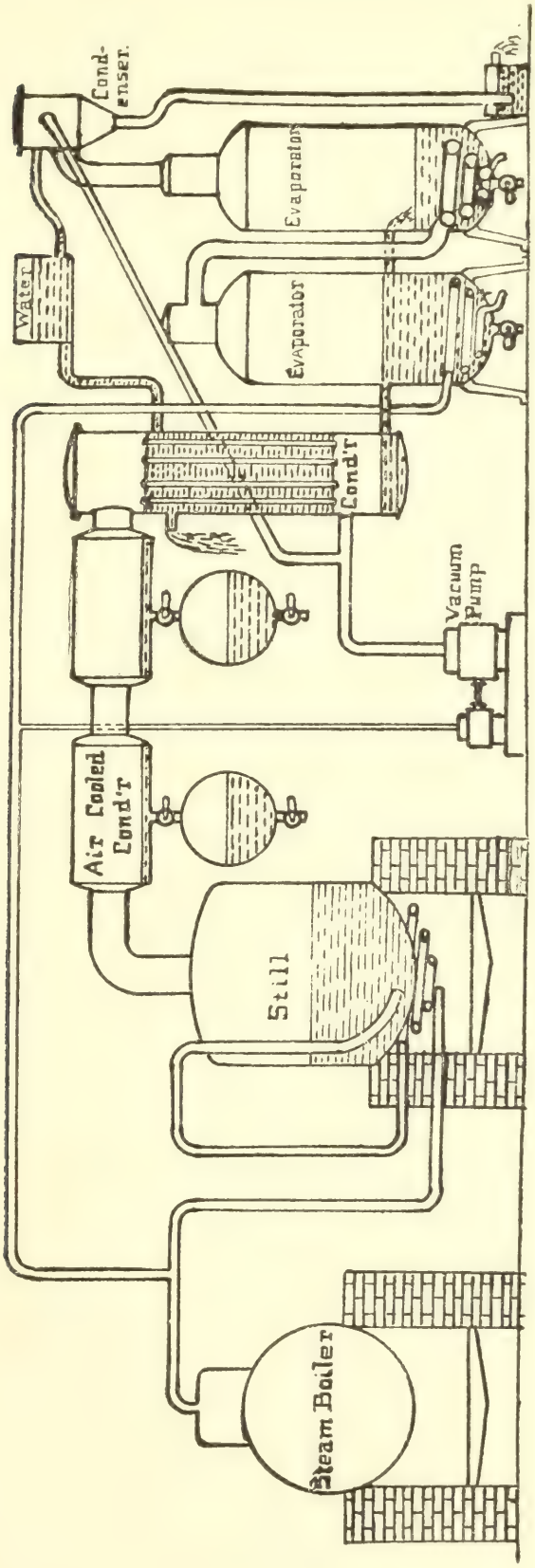

Cond-
enser.
Water
Evaporator
Evaporator
Cond'r
Vacuum
Pump
Air Cooled
Cond'r
Still
Steam Boiler

FIG. 4.

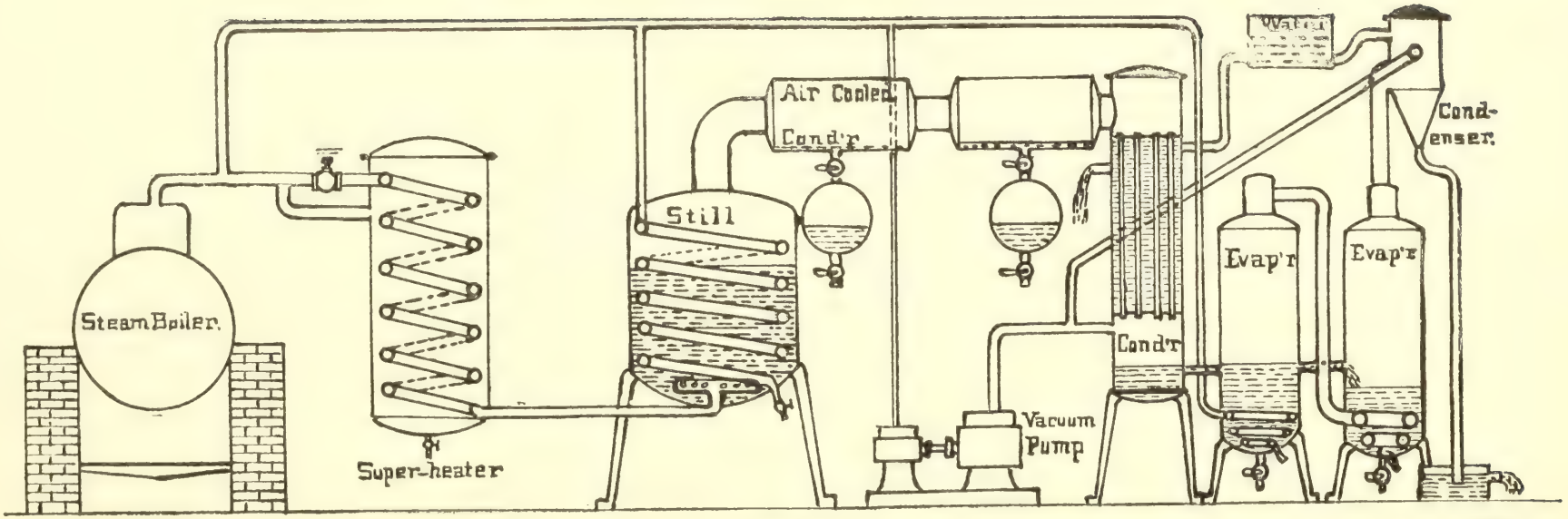

Steam Boiler.
Super-heater
Still
Air Cooled
Cond'r
Cond'r
Vacuum
Pump
Water
Evap'r
Evap'r
Cond-
enser.

Fig. 5.

glycerine to be vaporized. Fuel can be saved by heating the glycerine by this method, as the bottom of the still will not compare in value with the heating surfaces of a steam boiler in absorbing heat from a fire—more heat will pass up the chimney from the furnace of the still than from the furnace of the boiler.

In the Heckmann apparatus shown in Fig. 6, the next advance was made in the saving of fuel, as in this apparatus there is possibly but little " sweet water " to be evaporated. There are no air-cooled condensers in this type. The glycerine condenser is made up of a vertical series of annular pans fitting tightly in a cylindrical shell. Over the hole in the center of the pan, but sufficiently out of contact to freely permit a passage for the flow of vapor are inverted dish-like covers—the edge of the covers being below the level of the edges of the pans.

The level of the liquid in the pans is maintained just above the edges of the covers by means of overflow pipes adapted to permit a flow of liquid from the higher to the lower pans whenever the liquid reaches the overflow level. Above the glycerine condenser is a small sweet-water condenser adapted to condense a small portion of the vapor that passes through the glycerine condenser. The whole arrangement is such that the steam and glycerine vapors coming from the still must bubble up through the liquid contained in the pans, which is a mixture of water and glycerine; the water evaporates and the glycerine condenses.

The small sweet-water condenser at the top supplies the water to the pans, which in quantity should not be very far from the quantity of glycerine condensed in the condenser. The vapor which is not condensed in the sweet-water condenser is finally condensed in an ordinary condenser and according to the claims of the inventor contains so little glycerine that it can be run to the sewer.

In the Garrigue system, Fig. 7, an economical superheating of the steam as well as the condensation of some of the glycerine, are both obtained in the same piece of apparatus. The heat supply of this superheater is furnished by the hot vapor coming from the still which flows around the tubes of the superheater, while through the tubes passes the steam supply of the still. This steam supply is the vapor arising from the " sweet water " as it evaporates in the evaporator. This is one of the features conducive to the fuel economy of this system.

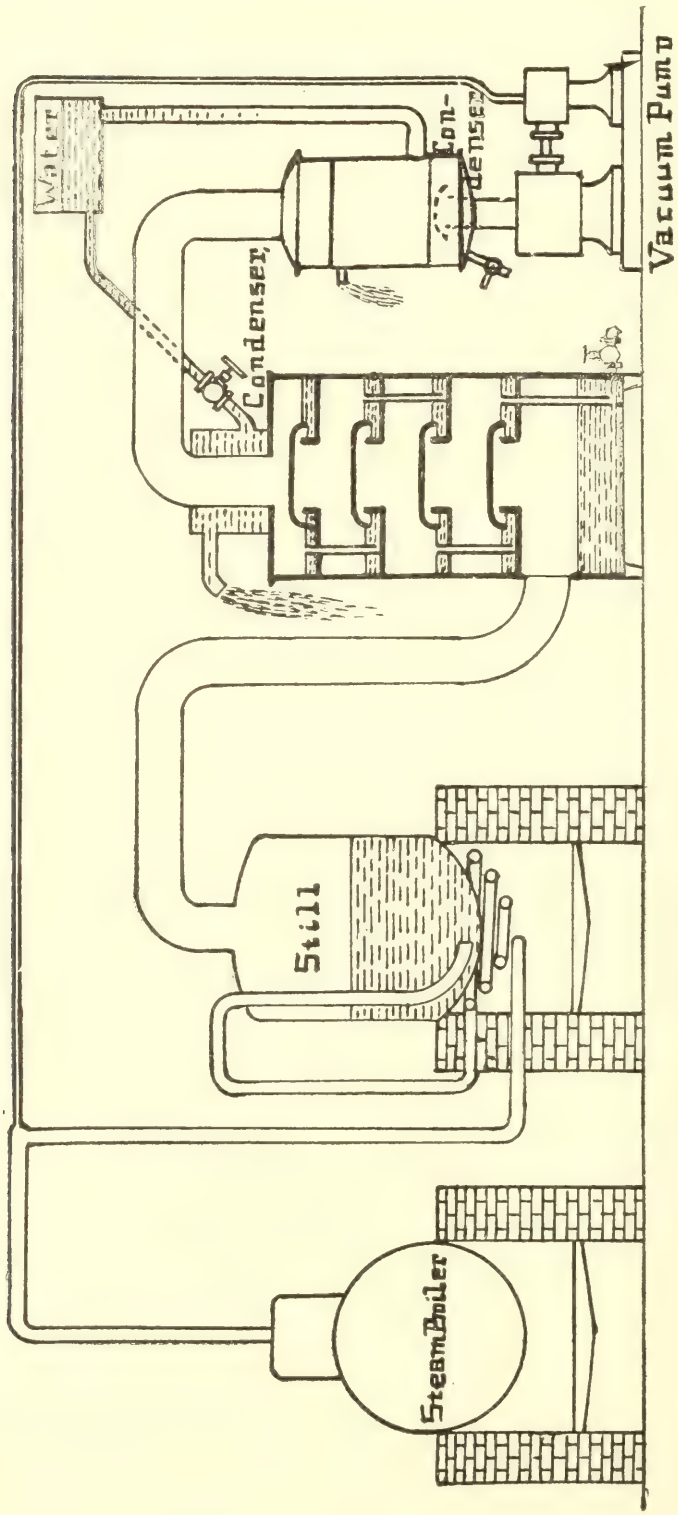


FIG. 6.

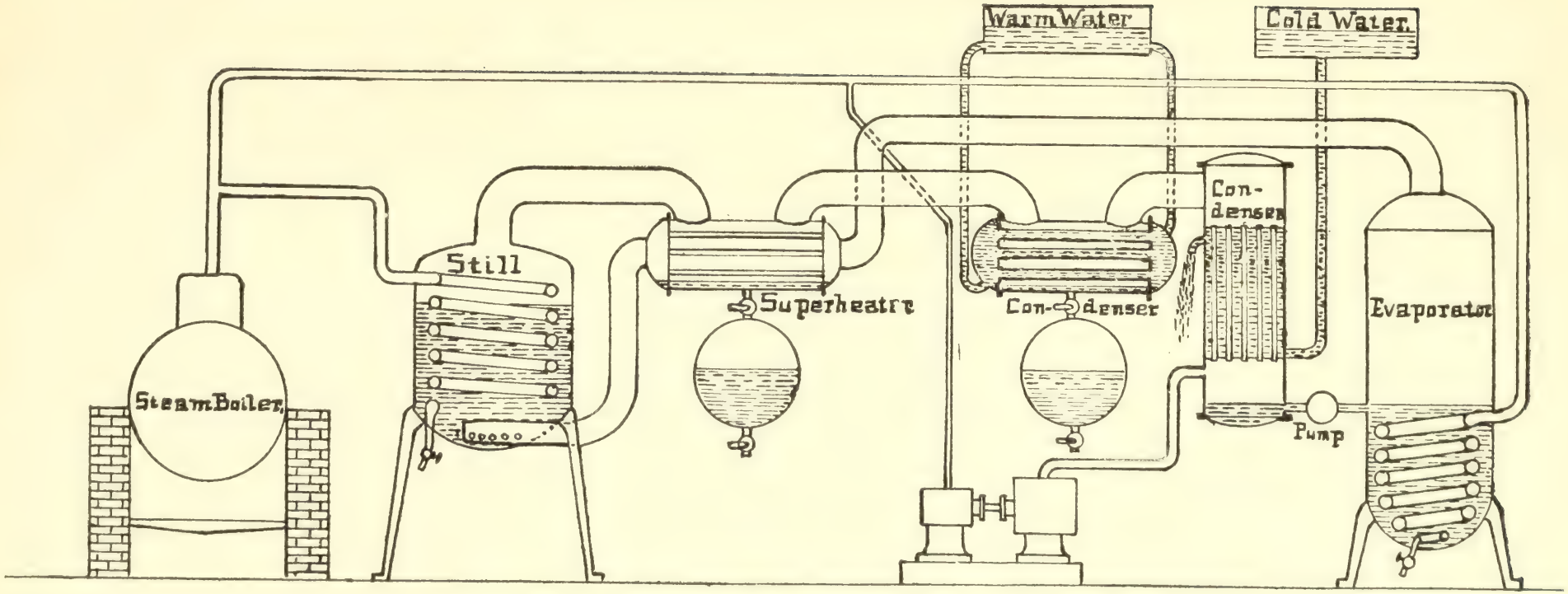

Warm Water
Cold Water
Con-
denser
Still
Superheater
Con-
denser
Evaporator
Steam Boiler
Pump

Fig. 7.

What glycerine is not condensed in the superheater is mostly condensed in a surface condenser, through the tubes of which circulates warm water. In all the above described systems evaporating—if any is done—is accomplished by steam directly from the boiler, or exhaust from the engine.

In the multiple-effect apparatus, Fig. 8, economy of fuel is obtained by using but one flow of steam to a number of stills and condensers, the stills being arranged in series in regard to the steam flow; that is, the steam from the steam jet of the first still flows through a series of stills alternating with condensers, the condensers being maintained at a temperature that will condense glycerine out of the steam but not the steam itself. The glycerine that is vaporized in each one of the series of stills flows along with the steam to the condenser next in line, the glycerine being condensed while the steam passes on to the next still.

The rather high condensing temperature in the condensers is maintained by using water boiling under a low pressure as a cooling agent. The steam generated from this boiling water of the glycerine condensers is used to evaporate " sweet water " and also to evaporate the water from which the steam flow of the stills is derived. This steam flow is generated in an evaporator which is fed with distilled water, so that no impurities will be carried over to the stills, with the steam. The heat absorbed in the vaporization of the glycerine is recovered when it is condensed in the boiling-water condensers. The heat thus transferred is sufficient to supply all the steam necessary for the stills and a large proportion of that required by the sweet-water evaporators. There is no difficulty in utilizing the exhaust steam from the engines, as there is always considerably more " sweet water " to be evaporated than that which is condensed in the cold water condenser or last condenser of the series. Washings from filter presses, etc., are a source of much sweet water.

An arrangement of stills and condensers in series along a single flow of steam necessitates a free flow without obstructions. Passing the steam flow from one still to the other of a series, and mingling it with the glycerine by steam jets beneath the surface is out of the question in this system, as too much back pressure would result from overcoming the hydrostatic pressure of the body of glycerine in each still. The first stills of such a series would be working at a great disadvantage, due to a low vacuum. The lower the

vacuum the higher must be the distilling temperature to get a good output, but a high distilling temperature is a cause of decomposi-

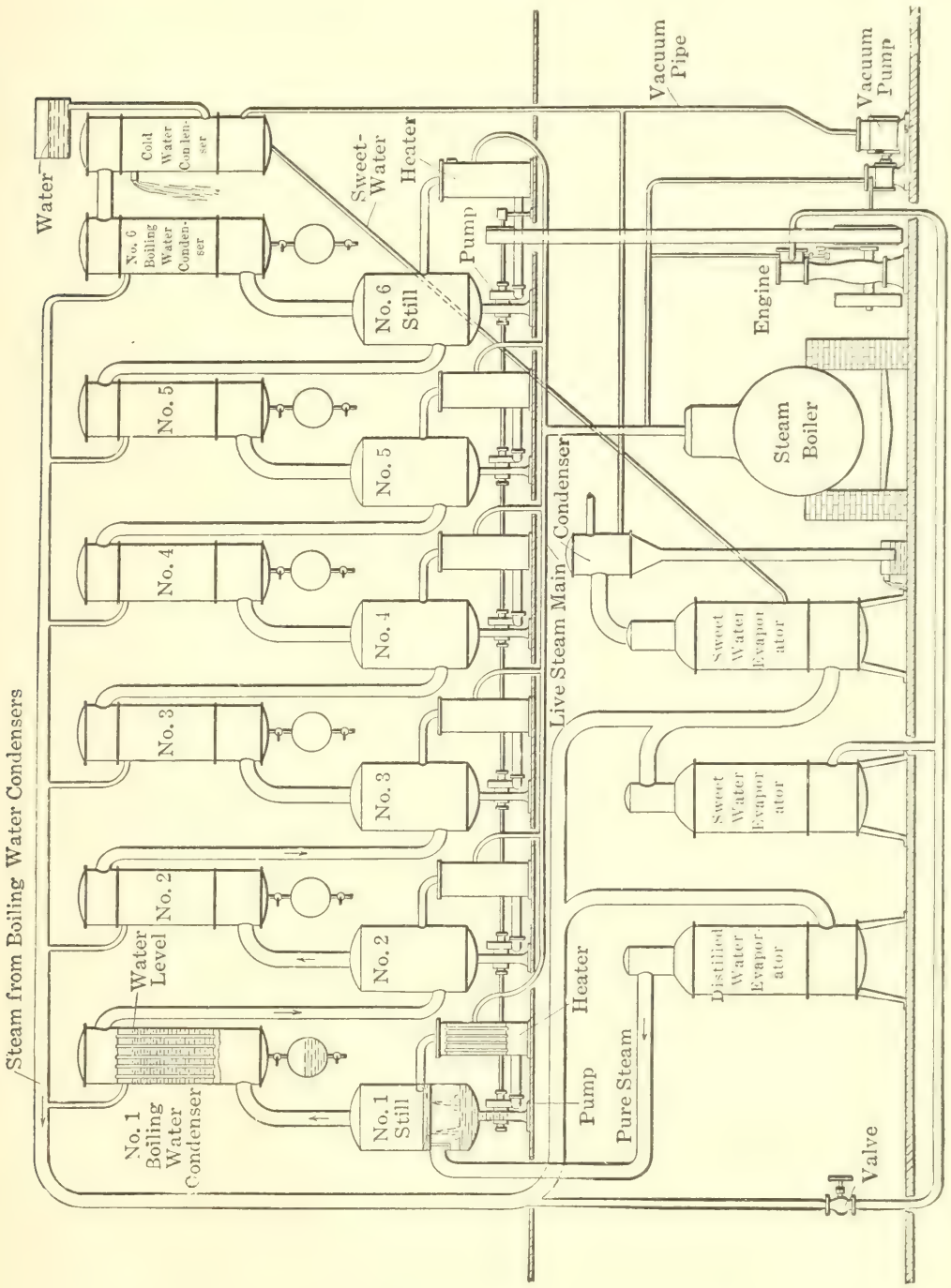


FIG. 8.—Wood Multiple-effect Stills.

tion. In this system, instead of forcing the steam down through the body of glycerine, the glycerine is pumped up and sprayed down through the steam, and no back pressure to the flow of steam results.

The amount of contact surface between the steam and glycerine is probably quite as great in this system as in the " jet below the surface " type; there is no reason why a great number of drops of glycerine falling through steam cannot present the same amount of contact surface as a great many bubbles of steam rising through liquid glycerine.

The high economy of distilling by this system can be better

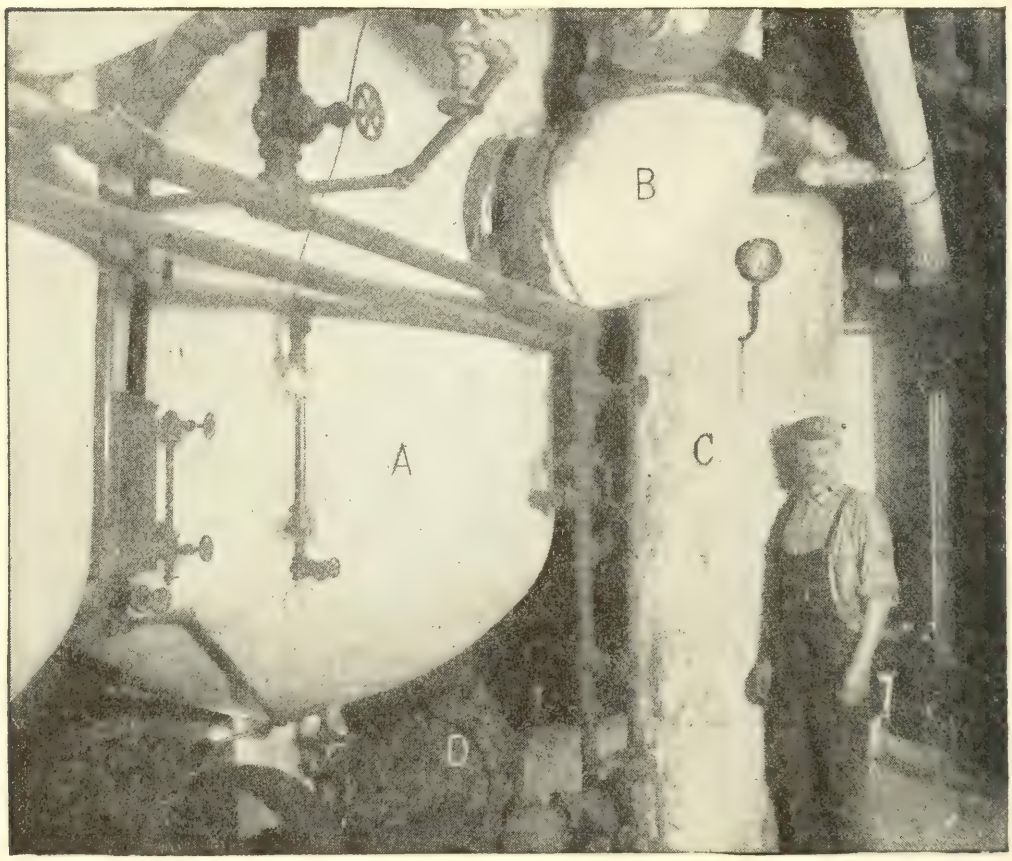


FIG. 9.—Wood Multiple-effect Stills.

A = Still. B = Steam Inlet. C = Heater. D = Circulating Pump.

appreciated by referring to Fig. 8, and following the course of the heat flow from the boiler to the final cold-water condensers. It will be seen that it leaves the boiler through the steam main, is carried along in the steam principally as latent heat. A portion is taken to operate the engine and vacuum pump, but the larger flow divides and passes to the heaters of the six stills. The heat is here taken up by the glycerine, passes, in the process of vaporization, to the steam and glycerine vapor, and is carried to the glycerine condensers,

where it is transferred to the steam arising from the boiling water therein.

The six flows from the boiling-water condensers then come together into one. On the way to the evaporators the flow again divides, the larger portion going to the distilled-water evaporator and the smaller portion joining forces with the flow of heat from the first effect of the sweet-water evaporators, which receives the heat of the exhaust of the engines, passes to the second effect of

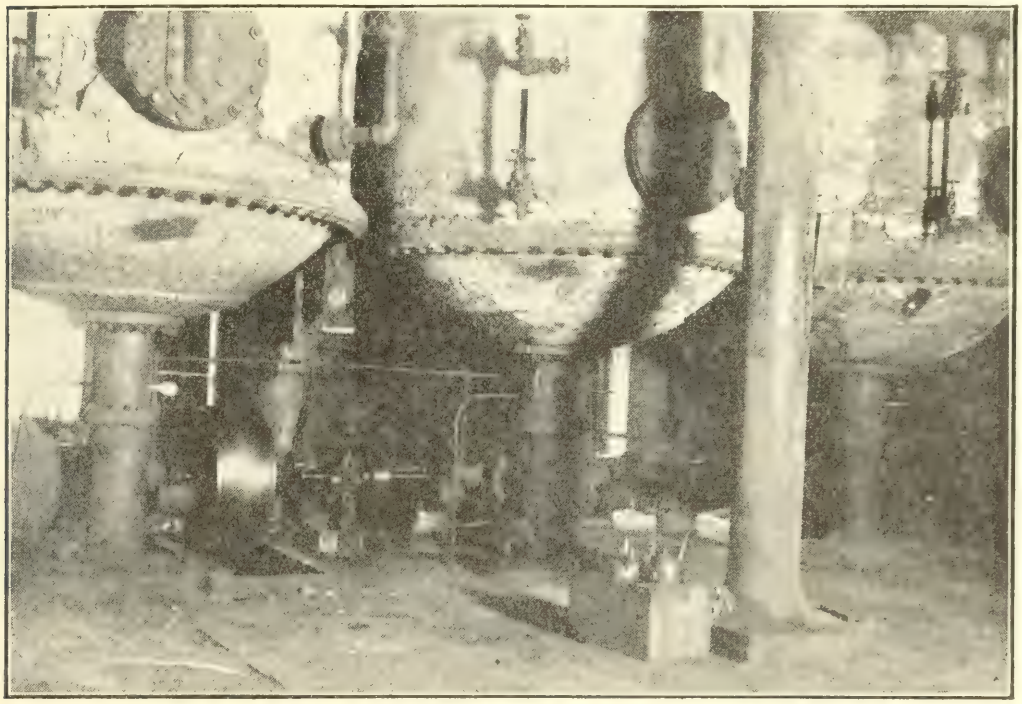


FIG. 10.—"A Group of Stills in Series."

the sweet-water evaporators, then along with the vapor to the jet condenser.

Going back to the flow of heat to the distilled-water evaporator, the heat flow passes into the pure steam arising from this evaporator, then is carried again to the stills; but this time, instead of dividing into a flow for each still, there is but a single flow passing from one to the other through all the stills and condensers and finally to the cold water of the sweet-water condenser.

THE ADVANTAGES OF THE MULTIPLE-EFFECT DISTILLATION OF GLYCERINE AND OTHER PRODUCTS

By A. C. LANGMUIR

Read at Philadelphia Meeting, Dec. 10, 1909

My chief object in adding anything to the interesting paper to which we have just listened is to state my personal experience with Mr. Wood's invention, as I believe the process to be one of real merit, which marks an epoch in the development of the glycerine industry. I have been familiar with the process at every stage of its development and with the practical working of it on a large scale at the plant of Marx & Rawolle in New York. Aside from the great decrease in steam consumption demonstrated by the practical use on a large scale where the output per still has been considerably increased, while the coal consumption was reduced to less than that formerly used, the chief point which distinguishes the process is the ease and steadiness of operation with a crude of varying quality and the uniformity in the purity of the distillate. Furthermore the process is at all times under thorough and scientific control.

The heating surface of the heater and therefore the speed of distillation can be increased to a point which cannot be reached by closed coils in a still. The rate of flow of the glycerine through the heater is dependent on the speed of the centrifugal pump and may be adjusted to the best conditions. The steam pressure maintained in the heater determines the temperature of the heating surfaces. As the three conditions mentioned are variable within wide limits any desired distilling temperature may be obtained and held within narrow limits. There has been no difficulty with the tubes of the heater becoming clogged with salt or organic deposits, for the current prevents any deposition of solid matter. In the process just described distillation is rapid

and only enough glycerine need be taken to fill the connections and heater. Under the old process a considerable body of glycerine must be kept in the still to obtain the full heating effect from the coils, which extend nearly the entire height of the still, and to prolong the contact of glycerine and steam from the open jets, so as to enable the steam to take up its full charge of glycerine vapor. A large excess of glycerine over and above that distilled must therefore be kept in the still and maintained at a high temperature for a long time.

In this connection the patent of Classen (German patent 198,768, 1907) is interesting. Classen obtains diglycerol and polyglycerol by heating anhydrous glycerine with small quantities of alkali or alkaline soaps. Prolonged heating of crude glycerine containing such impurities, in the average still must result in loss.

In the Wood process the glycerine is hot and anhydrous and there is no interruption of the distillation on account of stops for filling up or blowing out. A set of six stills in series, using one steam supply, is now successfully in use with no diminution in efficiency of the last still as compared with the first. All the stills in a series are under the same vacuum, which is uniform, as there is no necessity for breaking the vacuum, as must be frequently done in the old system whenever the stills are emptied and charged. The mixture of the steam and glycerine in the still by spraying is thorough and effective. It is noteworthy that in this system the hot glycerine superheats the steam.

When the steam is blown through a column of glycerine in a still under a vacuum in the old system great difficulty is experienced with certain crudes on account of the foaming and priming which takes place. Unless the distillation is coaxed by a careful regulation of the vacuum and steam supply, portions of the crude are carried over into the condensers, and in some cases the entire contents of the still pass over. Even with good crudes it is impossible to force the distillation by increasing the steam supply, for the limit of the catch-alls is soon reached, and the distillate is spoiled by entrainment. With the Wood process no difficulty has yet been experienced with shooting or foaming, even with varying crudes, for the glycerine is small in amount and is sprayed through the steam. It is not necessary for the chemist to be constantly testing samples from the condensers to detect entrainment, for the quality of the distillate is always uniform. A smaller

number of still men are required, as, to a large extent, the stills run themselves.

The glycerine is condensed from the mixture of steam and glycerine vapors by the boiling water condensers, the steam passing on to the next still in series to again take up glycerine vapor. Finally at the end of the series the steam, together with the volatile impurities distilled from the glycerine, are condensed in a cold-water condenser, the object being to eliminate from the steam at each hot-water condenser as much glycerine as possible in order that the steam may take up its full quota of glycerine at each still in the series and that the sweet water condensed at the end of the line will contain practically all the volatile impurities and a minimum of glycerine. The air-cooled condensers commonly used to condense glycerine from the steam glycerine vapor not only waste the latent heat given up by the condensation of the glycerine, but are variable in action, because they are dependent on the temperature of the air and its circulation, and are, of course, less effective in summer than in winter.

The boiling water condensers described in the Wood patent supply the means to maintain the temperature at any desired point found by experience to most effectually separate the glycerine at a given vacuum. The temperature is that of the boiling water, which, of course, is dependent on the pressure under which it boils, and may be maintained a constant by means of a suitable pressure regulator. It is obvious that such an apparatus is independent of weather conditions. This is an example of the principle of fractional condensation, which seems to be little understood by chemists outside of the glycerine trade. Doubtless there are many opportunities for its application in the organic laboratory, and in the manufacture of other distilled products.

With this plant a dynamite glycerine is obtained in one distillation from soap lye crude under working conditions, which will stand the most severe specifications met with in the trade either here or abroad, including the silver nitrate test for reducing impurities. The salt averages about half the permissible limit.

As to the use of the multiple-effect still in other fields, it is applicable in any distilling process where steam is necessary to assist the distillation and where the product has a boiling point higher than that of water. It could be applied profitably in the

distillation of the heavy products of petroleum and coal-tar, aniline, essential oils and the fatty acids of the candle industry.

Discussion

Of Papers by Mr. F. J. Wood and Dr. A. C. Langmuir

Secretary Olsen:

Where is the salt taken out?

Dr. Langmuir:

The distillation is not carried down to a point where the salt makes any considerable trouble. In several glycerine processes the glycerine after a certain point becomes so charged with salt that it constitutes what is known as "foots." Every glycerine factory has a plant for handling these "foots." The treatment of this material, which in the average refinery contains 30–40 per cent glycerine, is a problem in itself.

Mr. C. L. Reese:

It seems to me that there is considerable loss of heat in the large volume of "foots" taken away. I think Dr. Langmuir said that the process was continuous to some extent. I cannot see that there is anything continuous about it, because you have to stop to draw off this large volume of "foots."

Dr. Langmuir:

We do not take off a large volume compared with the original volume, and the heat which goes off is very slight compared with the total heat used in glycerine refining. The only heat lost is that which goes off in the "foots," which is easily computed. The heat going off in this way is a very small factor.

Mr. Reese:

I do not question the heat economy of the process, which is very evident. I am very much interested, and am very glad to hear the paper. The system is extremely interesting, very ingenious, and well worked out.

Dr. Langmuir:

There is no trouble in removing the "foots" in this process. The process is really not as complicated as it looks; the theory is very simple. You have perfect control of conditions. It is

possible to do with these glycerine stills just about what you please. You can run it continuously or intermittently.

Mr. Reese:

You get practically the same product, I understand, from each of the condensers?

Dr. Langmuir:

The product obtained from the condensers is really remarkably uniform when you figure the varying quality of crude which we have. We refine all kinds of glycerine. We do not have a single run of crude which is uniform in quality, and it was a very difficult problem to handle varying crudes in such a fashion that the output was uniform to specifications. With Mr. Wood's apparatus we have really been astonished at the output—the uniformity of the distillate, and the ease in working conditions. Formerly we had a great deal of trouble to keep some crudes in the still on account of foaming. Nowadays foaming is a thing of the past.

Mr. Reese:

It would be exceedingly interesting to have more definite figures on fuel economics.

Dr. Langmuir:

We cannot go into that, Mr. Reese.

Member:

Is the quality of the distillate from the final stills the same as that from the first stills? Those engaged in the manufacture of glycerine know that it is desirable to use as injection steam, pure steam, as is shown by the fact that in this apparatus injection steam is obtained by boiling water and not from the "sweet water." By the use in the later vessels as injection steam, steam which has come from previous vessels, and from which the fatty acids are not entirely condensed, do you obtain as good quality product from these latter vessels?

Dr. Langmuir:

I believe Mr. Wood, who is the father of the process, and who is the inventor, should really answer this question.

Mr. Wood:

The first still gives the best glycerine of the series. The glycerine that is in that still is the better quality. As we pass along

to the last of the series that is the poorest crude, so that any contamination from the first of the series will not have its effect on the last.

President McKenna:

Such a valuable invention as this could undoubtedly take up the time of experts upon the subject for a considerable part of the morning. There is very great suggestiveness in it for all those engaged in distillation of similar materials, but in order to keep to program, I will go right on.

ELECTRIC FURNACE FOR THE SMELTING OF IRON ORE

By EDWARD R. TAYLOR

Read at Philadelphia Meeting, Dec. 10, 1909

The applications of electricity to large problems in chemistry in the last few years have been so rapid and wonderful in their character as to awaken our keenest interest. Reactions heretofore beyond the reach of our thought by the older methods of chemistry are rapidly yielding to modern methods involving the use of the electric current, which obeys our bidding and goes where we send it, and keeps away from where we bar it off by our insulators and other devices. But it is not alone the extraordinary which attracts our attention by its unexpectedness—but ordinary reactions are done in extraordinary ways and in extraordinarily large units, and it is to one of these common reactions on a large scale that I desire now to call your attention.

The electric furnace for the manufacture of carbon bisulphide leaves nothing to be desired when applied to reactions of that kind—either in the application of the electricity or in its management. The use of broken or fragmentary carbons, fed upon and between the main electrodes of such a furnace, fulfills so important a mission as to make what electricians are fond of calling a "fool proof" construction.

In practice we have repeatedly found it possible to shut the furnace down completely, and when perfectly cold start it up again with ease and certainty. Fig. 1 shows the arrangement of this furnace, in which at *d* are shown the main electrodes and at *l* the broken carbons falling down upon them and over their ends, the object of which is to take up current from all points of contact with the main electrodes, saving them from heavy wear, and carrying the resistance or weakest part of the electric circuit farther away from the electrodes themselves and into the

center of the furnace, where the heat should be the most intense and concentrated. This saves moving the electrodes through the walls of the furnace. In manufacturing a substance like bisulphide of carbon, which evolves a disagreeable gas, you must have absolutely closed chambers, and to move an electrode through such a closure is very difficult. We have been using this method

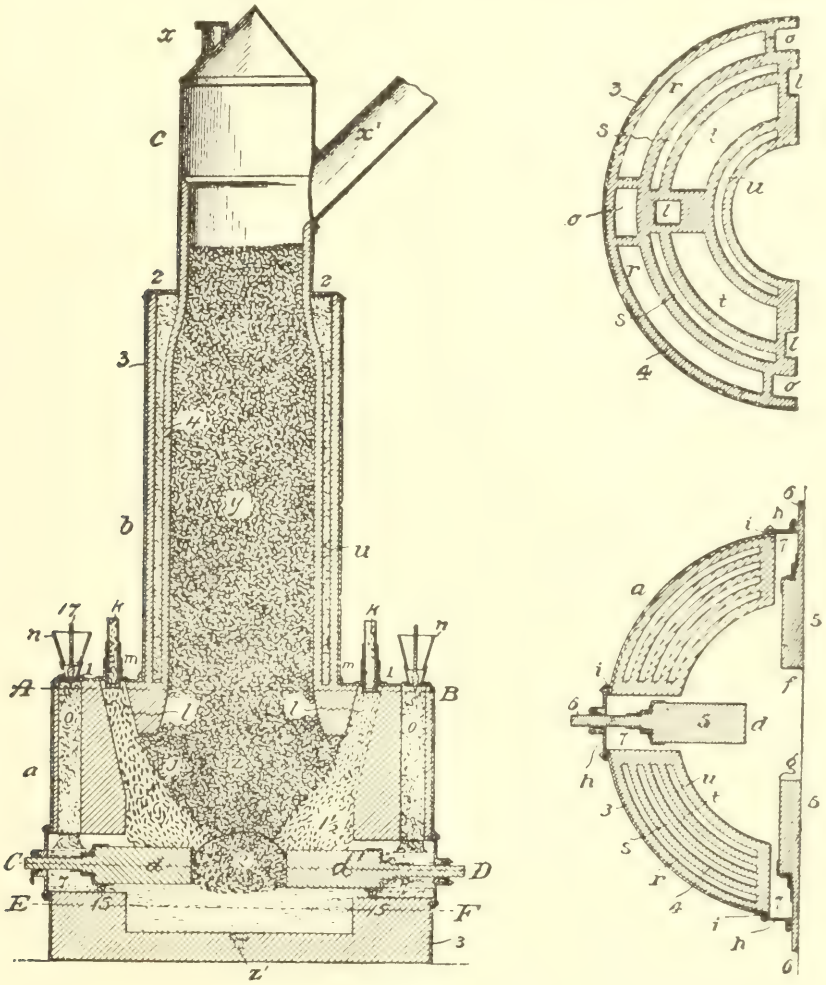


FIG. 1.

for more than ten years successfully, making these movable or broken carbons *virtually* the movable electrode. They fall down on the main electrode (just above *d*, Fig. 1), and carry the current into the furnace, the breaking-down point of the circuit being in the center at (2), so that as a matter of fact we do not have excessive heat except in the interior of the furnace. This is an important feature of this furnace.

Sulphur is fed around the periphery (at 17, Fig. 2) of the furnace, and as it melts carries the heat absorbed into the interior.

It also forms a blanket around the heated interior. The sulphur melts in the channels and comes into the furnace at 3, Fig. 2. When handling an infusible material like iron ore the problem is very different, and you will see some modifications which I have introduced to accommodate the different conditions. You

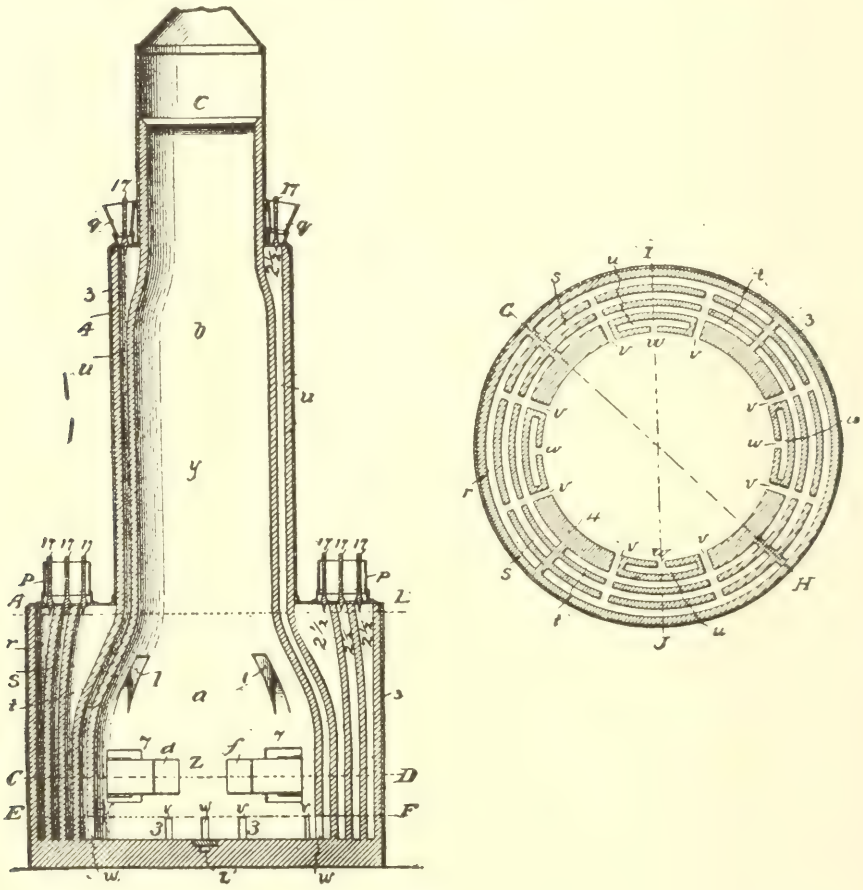


FIG. 2.

can readily see that making a blanket of any material around a central heated zone makes the material a carrier of heat into the interior.

Figs. 3 and 4 show another form of hip with four main electrodes and with the columns of broken carbons falling down upon them, and performing the same functions as just described with reference to the carbon bisulphide furnace.

I have for several years been studying the application of these

general principles to the electric smelting of metals and especially of iron ores, in a construction designed for work on a larger scale. There are several important advantages in such large-scale work, and the ability to concentrate the electric heat in the center of

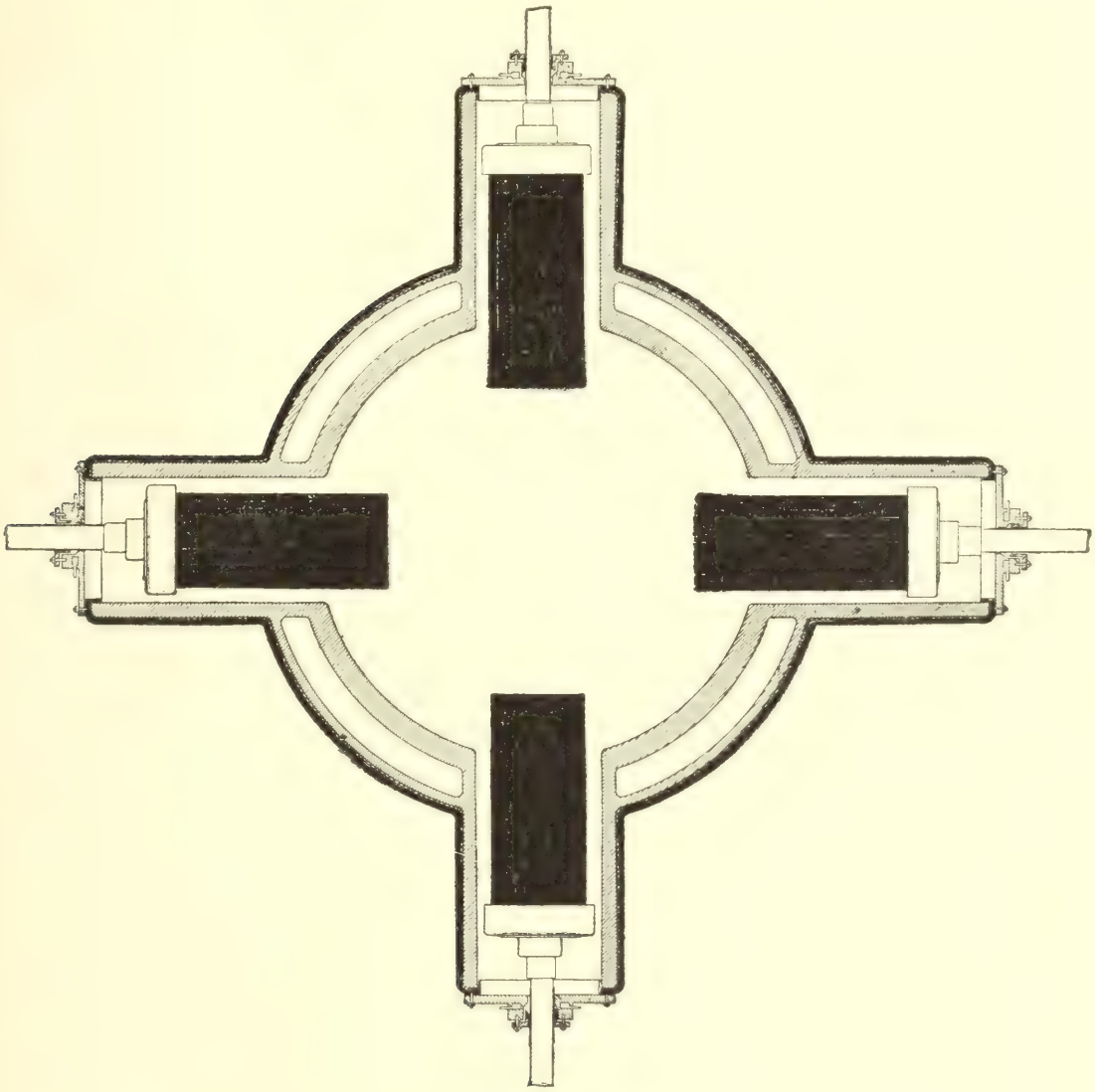


FIG. 3.

such a furnace adds to the advantage of large-scale construction and operation.

In the case of the ordinary blast furnace for smelting iron the heat is very uniformly distributed through the furnace from the bottom upwards in such a way as to be very severe upon the lining of the furnace itself. On the other hand, in the electric

furnace, with the greatest heat in the center, the lining is not only immune form excessive wear—but may by judicious management be practically relieved of being a lining at all, becoming simply a shell to direct the course and fall of the charge itself, which in a very important sense becomes a movable lining of the furnace

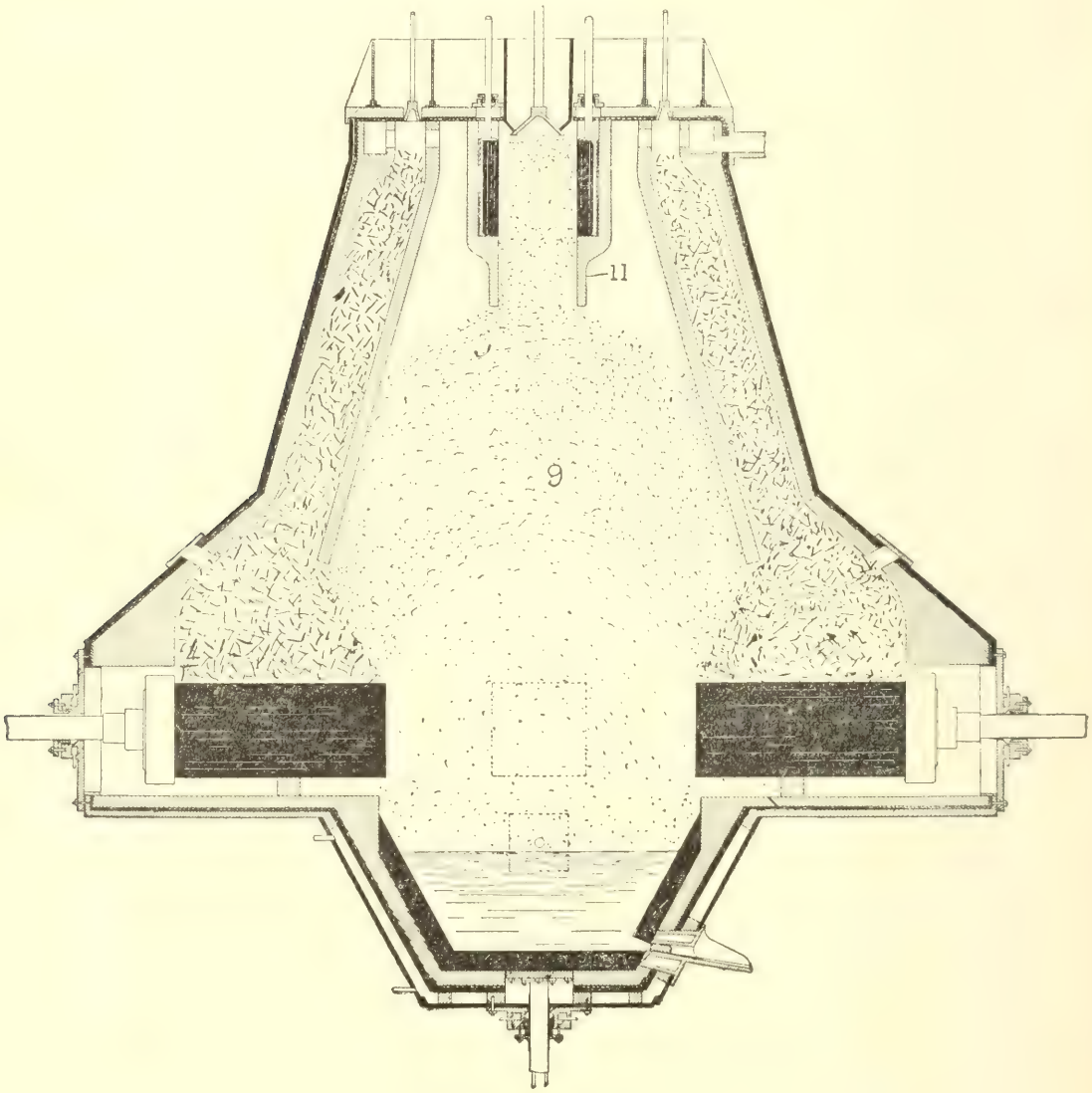


FIG. 4.

itself. This is very clearly shown in Fig. 7, where the ore mixed with fluxes and with carbon, if desired, is shown descending into the furnace upon screws near the periphery, placed there in the cool part of the furnace to force the descending charge towards and into the central heat zone. The position of these screws is

higher in the furnace than the electrodes and their relations are more particularly shown in Figs. 8 and 9.

There are four electrodes, and the path of the electricity is through and through. We usually use the two-phase current: one phase through the electrodes 4, Fig. 5, the other through the electrodes 5, Fig. 5. If impediments are formed, e.g., piers may build up between, we can readily switch the current, 6, Fig. 5, but the furnace can be run for months without having to reverse the current.

The heat is centrally located between the electrodes. The raw material forms a movable lining. We have never had to replace the actual lining. So far as working ability is concerned the linings are just as good as when they were put in.

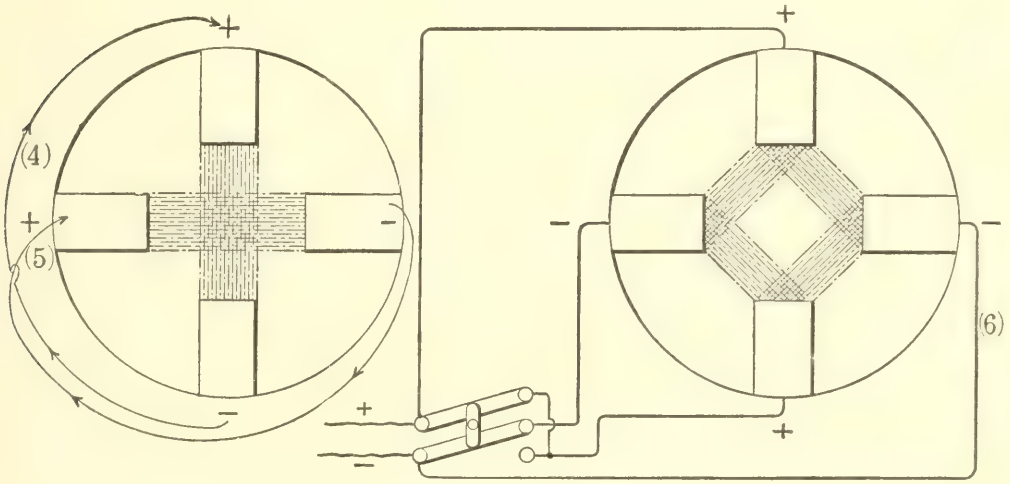


Fig. 5.

In Figs. 6 and 7 is also shown at *i* a sleeve or directive feeder through which charcoal is fed. In Fig. 6 the charcoal is shown to spread out across to join the column of broken carbons on each side—being so directed by baffle walls, shown more clearly in Fig. 8.

Diagonally from this view the charcoal which comes down through the furnace from *e*, Fig. 6, may spread out toward these broken carbons, which are fed down between the curtains you see at *i*, Fig. 8. This makes a diaphragm right across Fig. 6, so that we feed in the charcoal at *e*, Fig. 6, and the broken carbons at *h*, Fig. 6 at the four points, and as they come down together below this sleeve, which is shown at 11, Fig. 4, and at 12, Fig. 8, it spreads out as shown at 9, Fig. 4. Then the coarse ore is fed

in at the hoppers at *f*, Fig. 7 (also see Fig. 10), and the fine ore fed around the periphery at *g*, Fig. 7, and at 16, Fig. 7, and comes down through two different channels, 17, Fig. 7, but joins more or less at the bottom. At these points there are

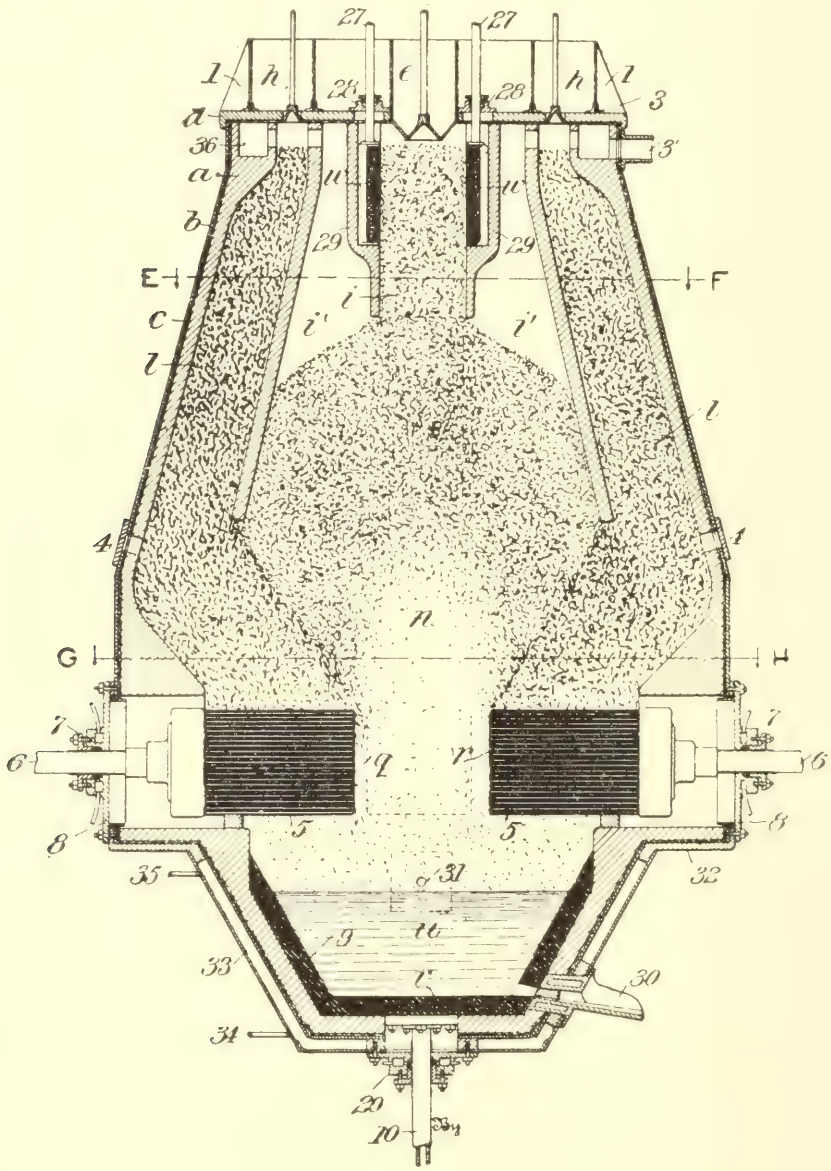


Fig. 6.

baffle plates, *p*, Fig. 7, and they allow a circulation of gas under those plates, and at the bottom the plates are cut away, so that more or less of the fine ore, 19, Fig. 8, falls over into this coarse ore. The charcoal maintains itself clear down through the whole.

One object of this is to prevent the furnace from becoming too conductive of electricity. Charcoal is not as good a conductor as the broken carbons. If you maintain charcoal down through the center you can keep the conductivity of the furnace in a more

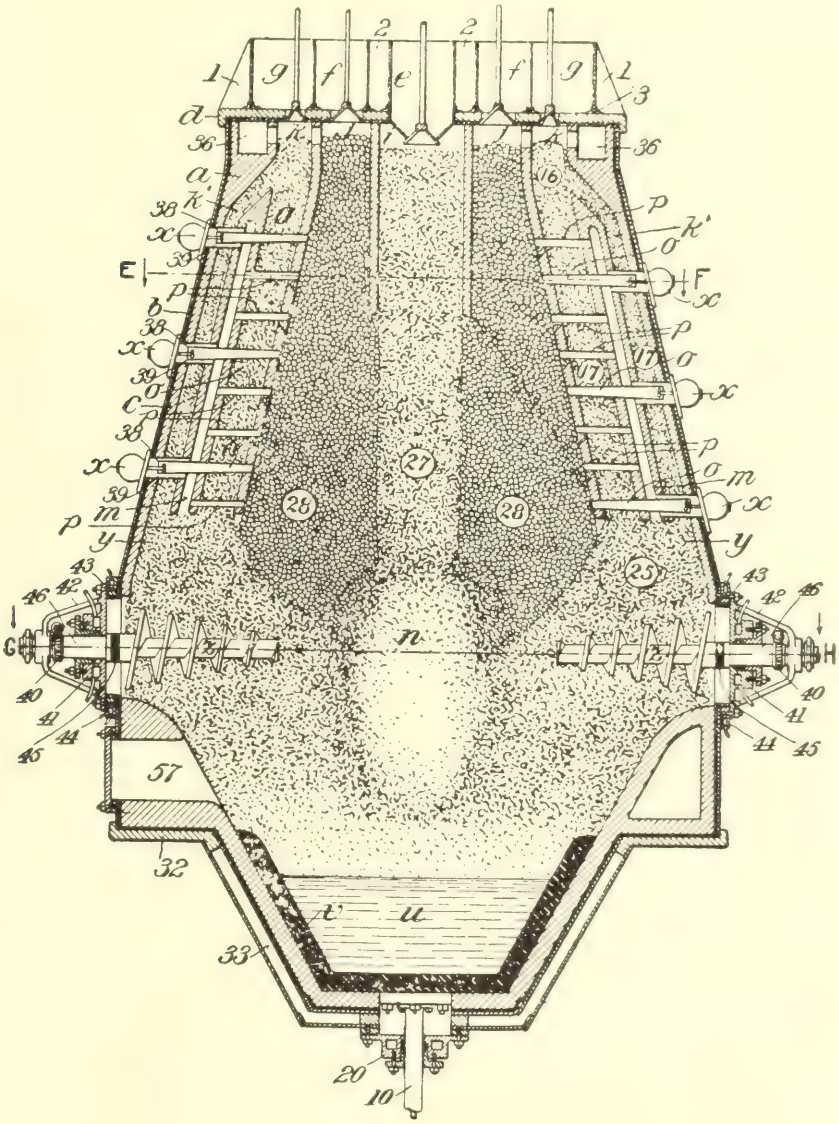


FIG. 7.

manageable condition. This differentiates the ore and the fuel in an entirely different manner from that employed in the ordinary blast furnace. In the blast furnace the alternate charges of one and the other form horizontal layers. In this electric furnace the layers are perpendicular. There is small chance for the ore

to get together and small chance to make a carrier of electricity through the ore itself, which may under certain circumstances become more conductive.

In loading the furnace to start with the space at *q* and *i*, Fig. 8, is mainly filled with charcoal with only sufficient broken carbons to insure the starting of the furnace in the cold condition, and it is designed that this column of charcoal (more easily seen in Fig. 7) shall always remain between the electrodes to help maintain a high resistance in the furnace—and to keep the columns of ore in the four quarters of the furnace from joining each other and thus raising the conductivity of the furnace too high for advantageous working.

These protective channels are shown a little more clearly at 8, also at *y*, Fig. 8. As the ore comes down it strikes these screws (you see the end of one of them right through the arch at 20, Fig. 8). They stand above the electrodes—not immediately above, but at another quarter of the furnace. (See Fig. 9.) For example, you are not looking right directly at the end, but at the side of the electrode *S*, Fig. 8. The arch through which they come is seen at 22, Fig. 8. Now the charcoal as it comes down is allowed to spread over in these channels so that it makes a web across and keeps the ore as shown at *n*, Fig. 6, from joining clear around the furnace. Now it would look as if it were a very complicated structure, but if you start at 23, Fig. 8, you can see that we can put the arches up very well without any difficulty, starting at 24, Fig. 8. The fact must be recognized that we have entirely different conditions from those in the blast furnace where the lining has as hard service as any part of the furnace. With the heat in the interior, as in the electric furnace, we can do what we could not think of doing in the blast furnace. The fine ore comes down until it strikes the screws. The screws are not placed in the hot portion of the furnace. If the proportions shown at 26, Fig. 8, are too long we can make them shorter. They are packed in the arches in such a way that they are not in contact with the hot part of the ore. That which comes down on the outside is the coolest portion of the ore. It has only absorbed heat from radiation. It has not had the gases going through it. I spoke of these baffle plates 19, Fig. 8, where more or less of the fine ore sifts through. The place of this fine ore *o*, Fig. 7, is taken by cool ore coming through at *y*, Fig. 7, so that as it gets down

to 25, Fig. 7, the whole tendency is for the ore which is coolest to keep on the outside. In this way heat is carried back into the furnace. We endeavor to do with infusible material what we can very readily do with fusible material like sulphur, and in that

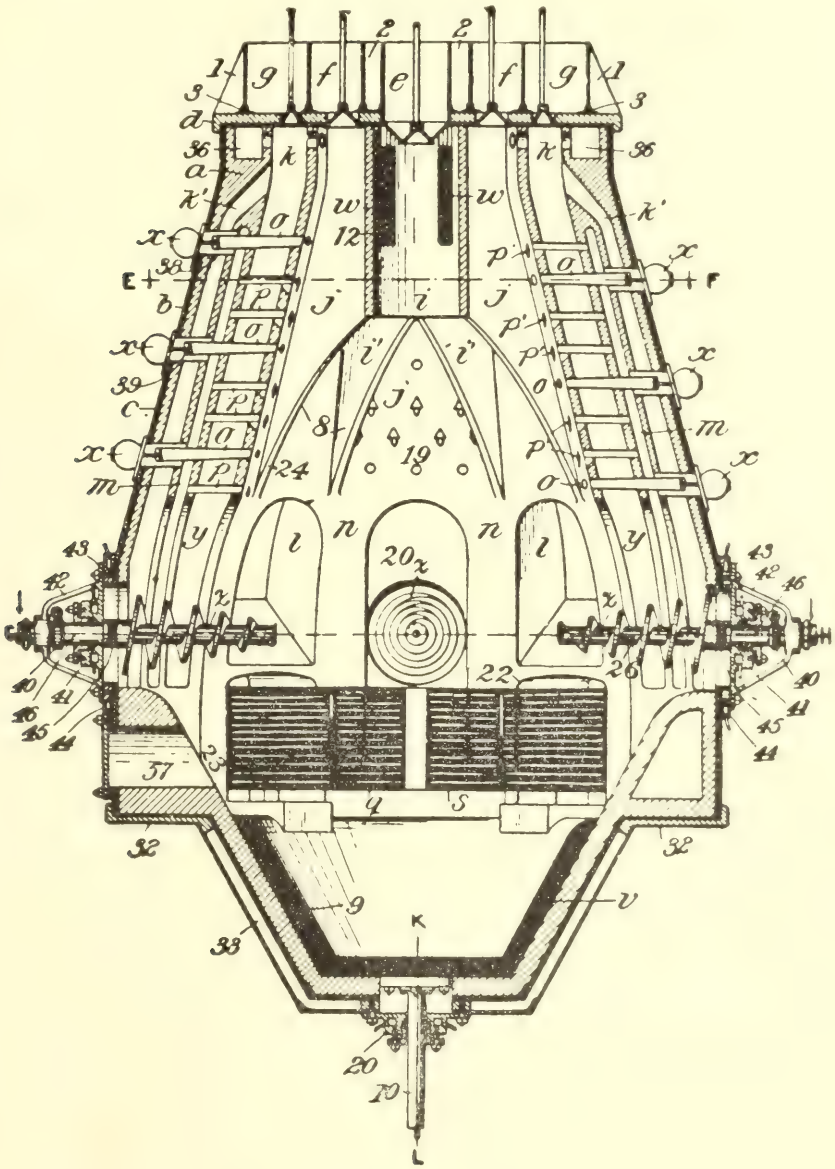


FIG. 8.

way to utilize the principle of the carbon bisulphide furnace in connection with materials which are infusible except at high temperatures. With the ore coming down in this way, and with the charcoal maintaining itself down through this perpendicular

column in 27, Fig. 7, preventing these materals from getting together, we have the concentration of the heat right in the center of the furnace.

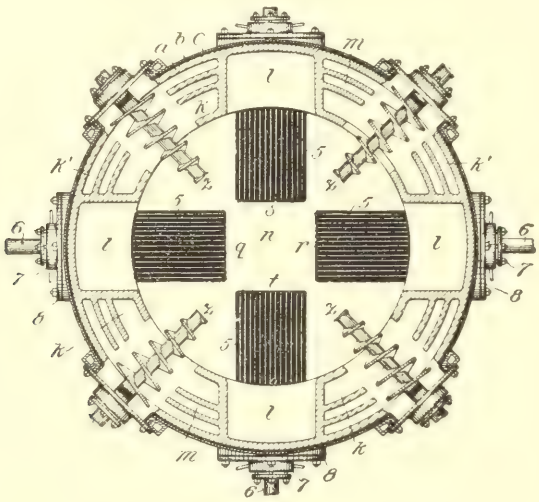


Fig. 9.

It will be noticed that coarse ore with fluxes is fed in at *j*, Fig. 7, and that fine ore with fluxes is fed in at *k* around the periphery of the furnace. Carbon can be mixed with these columns of ore if necessary—for the complete reduction of the ore. It is not

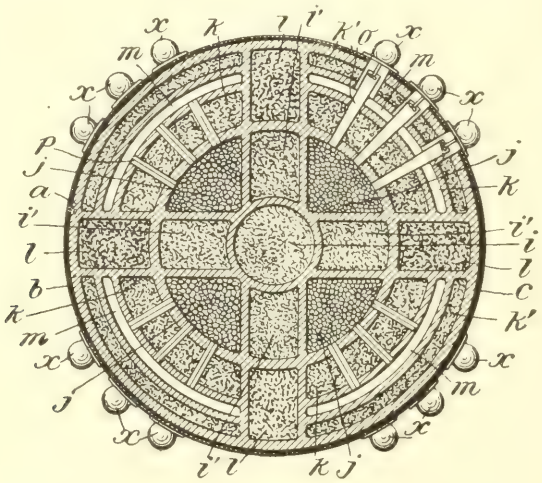


Fig. 10.

designed that ore shall get down between the electrodes either for reduction or melting—but that both of these operations shall take place at a higher point in the furnace and that as fast as melted it will run down between the electrodes in drops or streams to

the hearth of the furnace. The hearth of the furnace is lined with electrode material (carbon) and may be connected with an electric circuit at 10 and 57, Fig. 7, respectively, and operated either intermittently or constantly as may be found desirable. Tap holes at 30 and 31, Fig. 6, respectively, are arranged for removing the slag and molten metal from time to time.

As is well known, the reduction of the iron ore in the blast furnace is done more by the CO than by actual contact with the carbon, and I have not attempted to show how the carbon can be mixed with the ore, though it is practicable to do so, if we wish a certain quality. The reduction depends mainly upon the circulation of CO. The first which takes place after applying heat is the formation of CO_2, which is soon reduced to carbon monoxide, the carbon combining with any oxygen within reach. As fast as the carbon monoxide comes in contact with the iron ore at sufficient temperature, it will take up oxygen and be oxidized to dioxide. This carbonic acid may then be drawn through under these baffle plates *j*, Fig. 7, 8, and by means of small fans, *x*, Fig. 7, 8, run by electric motors on the outside, run back through the coarse ore, 28, Fig. 7, and into the column of charcoal, 27, Fig. 7, and be reduced again to the CO condition, and thus it may be migrated several times until it reaches a point so high that it is no longer hot enough to react with the oxide of iron. It is intended to make the CO do more duty as a reducing agent than it generally does in passing right up through the furnace.

It may be interesting to note the use of expanded metal in the construction of the electrodes in Figs. 11 to 16, by means of which the conductivity of the metal holder of the carbons is made to extend into the electrodes and thus relieve the carbon part of them of the necessity of carrying all the electricity they deliver through the whole length of their course. In other words the electricity is taken up gradually from the metallic part and the carbon does not have to do it all until near the end of its duty, a feature which all will appreciate who have used electrodes with low-voltage current.

The method of construction is shown in Fig. 15. I have figured expanded metal, cut in squares and then pulled apart, so that carbon can be forced down in between (Fig. 16) these meshes of of the metal, which carries a certain amount of the electricity, without requiring the carbon to carry it all. In that case the

electricity will travel through the metal more easily than through the carbon itself, and consequently there will be a less severe strain upon the carbon. Of course if the metal being produced comes in contact with the metal it will simply be fused, but it will relieve the wear on the electrodes very much.

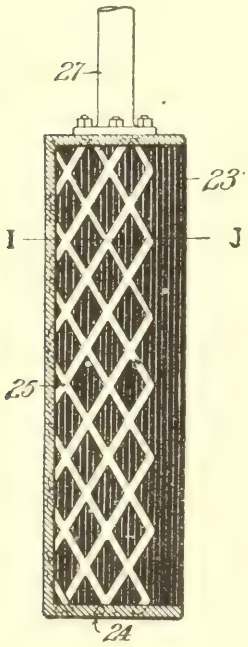


Fig. 11.

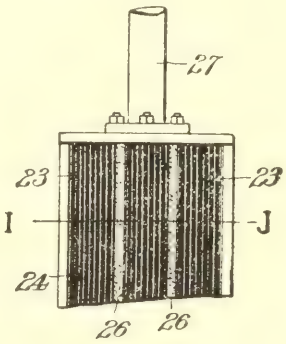


Fig. 12.

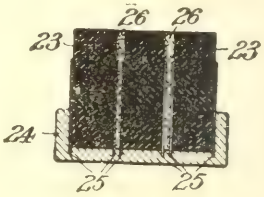


Fig. 13.

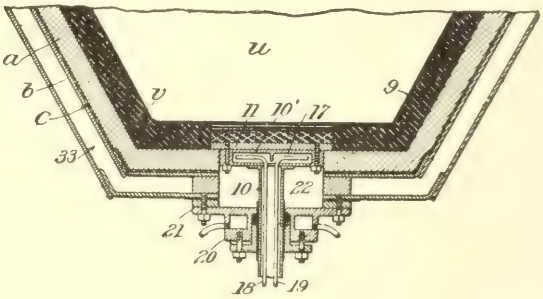


Fig. 14.

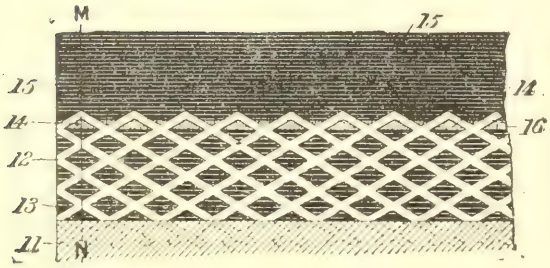


Fig. 15.

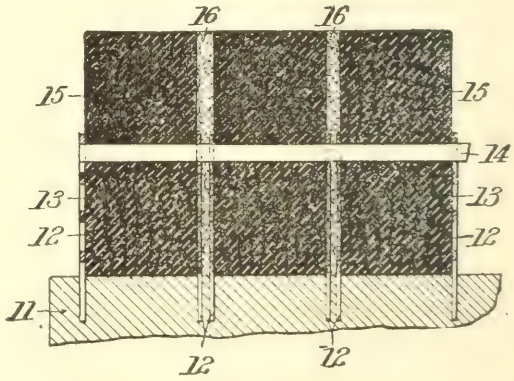


Fig. 16.

To facilitate the reduction of the ore—there are shown in Fig. 8 baffle plates around and past which the fine ore descends, leaving a passageway under them (being preferably triangular in shape and placed with the ridge up), through which the CO from

the interior hot part of the furnace may pass, and reduce portions of the ore, then passing into a chamber from which it is exhausted by little fans connected with motors, *x*, on the outside of the furnace, by means of which the CO_2 so produced is forced back into the central hot part of the furnace in contact with hot charcoal, which again reduces the CO_2 to CO, which process is repeated till the gas has reached so high a point in the furnace as to become too cold to react in this way.

While the description of this may seem complicated, it will be noticed in Fig. 8 that the arches supporting these directive channels are simply and easily constructed and are so protected from the heat as to make them very enduring—the design being to so direct the several descending columns of material as to prevent either the ore or the reduced iron from making the furnace too conductive of electricity to work regularly and easily, and also to compel the coolest ore to follow down the periphery of the furnace till forced into the interior either by the screws referred to or by the course of its natural descent. It is indeed intended that the descending ore should be, as it were, a moving lining of the furnace—constantly making its way downward and at the proper time into the central heated part of the furnace—saving absorbed heat that in ordinary furnaces would be radiated away and lost for the reaction, while when such material does reach the interior of the furnace it is at so high a temperature as to offer no chilling influence, and heat is applied to the best possible advantage.

We may now examine a little more closely the main electrodes and their reinforcement with broken carbons. Let us bear in mind that the movement of these broken carbons as they wear away takes the place of the movement of the whole electrode in the common and ordinary use of electrodes, and that they are in reality a part of the electrode itself to all intents and purposes; and that the wear on the electrode proper is comparatively slight and that they do and will last during many months of consecutive use; and that the function of conveying electricity into the reaction zone is more regularly and completely done than by means of an electrode that is moved through the walls of a furnace.

In practice in the carbon bisulphide furnace, 16 feet in diameter and 41 feet high, I use electric-light carbons, but in a furnace for smelting iron ore, which would be made very much larger,

I would use larger pieces of broken carbon—as large as your fist or more. In that way it would keep a more open surface at the bottom, and would serve equally well for carrying the electricity. You can see that with materials handled in this way, it is not a thing for small work. In the early part of the carbon disulphide work we experimented with a furnace 4 feet in diameter. It was so small that we found it very difficult to make things work; with a furnace 10 feet in diameter it was much easier, and easier still with the 16-foot furnace, and with a furnace of this size we run right along for months at a time.

We are now prepared to recognize that the ore and fluxes and carbon all have their regular descent, and that the ore as soon as it reaches the temperature of reduction by CO, is in an atmosphere of CO, and that the complete reduction will take place before it reaches the temperature of fusion—for the space in which to move is ample, and the approach so gradual that nothing precipitate takes place, and as fast as any portions reach the point of fusion and have sufficient temperature to liquefy, drops of molten metal are formed, and find their way quickly to the hearth of the furnace preparatory to being tapped off as shown at 30, Fig. 6—either as a constant stream of metal or from time to time, as may be found to be expedient. Another tap hole is provided for the slag at 31, Fig. 6. Electrodes are provided at the top and at the bottom of the furnace which may form a circuit (preferable from another source of electricity) either with each other or with the main electrodes. In either case such a current of electricity through the charcoal column *i n*, Fig. 7, will have a tendency to keep said column in a state of incandescence and in a condition to reduce any CO_2 to CO that comes in contact therewith. By means of the circulatory system already referred to, the reduction of ore and of CO_2 to CO should be active and often repeated as the gases make their way out of the furnace.

This being a perfectly closed furnace, the gases passing out at 36, Fig. 7, may be utilized in gas engines, for heating, or other useful purposes. There being no air blown in there is no inert nitrogen to be in the way of active reactions, nor to carry heat away in its exit from the furnace—nor any water vapor introduced by such blast to absorb heat or interfere with the reactions within the furnace.

The coarse ore is fed in on four sides of the charcoal pyramid

shown from *i* to *n*, Fig. 7, and fine ore in the outer channels as shown in the same figure.

The charcoal spreads out in four ways towards broken carbon channels as shown in Fig. 6, being kept separate from the ore by the divisional arches shown at *i* in Fig. 8, and alternately joins the columns of broken carbons descending through the arches shown very nicely at *l*. The design of this arrangement is to divide the ore into four quarters or columns—shown more clearly perhaps in Fig. 10. One main object in these divisions is to interfere with any matting together of reduced iron clear across the furnace with the danger of a hold-up—or the danger of forming so good a conductor from one electrode to another as to short-circuit the furnace.

I have deemed this question the hardest of solution in a stack furnace and feel satisfied that it is fully provided for.

It may be noted again that coarse ore is fed in a column separated from the fine ore that surrounds it, but more or less of the fine drops into the coarse as it descends through the openings *j*, in Fig. 8, leaving behind it some cooler ore to take its place—and to descend nearer to the exterior of the furnace. The object of this surrounding mantle of fine ore is to conserve the heat seeking to escape from the sides of the furnace by radiation, the endeavor being to make an infusible ore at that temperature perform in this respect the same function that sulphur performs in the carbon bisulphide furnace.

We should not lose sight of the fact that in reality there is no lining to this furnace in the sense that we ordinarily understand the term. The charge itself in reality becomes the lining. The shell and channels are really directive agencies to compel the materials to go where we want them to, and to be influenced by heat and the other agencies under predetermined conditions.

Studying carefully the skeleton shown in Fig. 8, two of the main electrodes are shown at *q* and *s* in their arches, and above them the arches *l*, communicating with the broken carbon channels. Looking directly ahead and just above the electrodes is shown one of the screws in its arch and on either side another view of two screws—with half of the arches in which they stand and operate and above these are clearly shown the two channels down which the fine ore descends upon them. The ore in the outer one of these will always be comparatively cool—for it has only been

subjected to radiant heat seeking escape and therefore absorbed.

Turning again to Fig. 7, the movement of materials can be readily traced. The heat zone is in the center at and below *n*, towards which all the charge of the furnace tends both from the top and the sides. Thus the blanket is constantly renewed from the outside and constantly descending, to be taped (31, Fig. 6) away in the form of molten slag or metal.

I may not detain you longer than to say that this furnace is designed to meet the demand that will soon be upon us for a really large-scale furnace for the smelting of ores. For though iron ores are specifically spoken of it is deemed with slight modifications to be well adapted to the smelting or working of many classes of material.

Mr. McKenna:

This is an admirable and epoch-marking paper, Mr. President. Nobody who has experimented on electric furnaces but remembers the apparently insuperable difficulties, which many said were unsurmountable, connected with the decay of electrodes in air, and with the utter impossibility of finding any practicable refractory material for such a heat, and to see now that the problem is solved—and I think it is practically solved—by using the materials and substances themselves as insulators, producing a little laboratory in the very heart and core of the whole apparatus, where only that high heat is availed of, and it is almost fully availed of, is really an admirable and important advance. I did not hear Mr. Taylor mention limestone or flux. I assume it goes down with the ore.

Mr. Taylor:

Yes, I should have mentioned that.

Mr. McKenna:

Did I understand also that a very large amount of CO escapes?

Mr. Taylor:

Yes, sir.

Mr. McKenna:

Then there is room for further advancement in heat economics by having a downtake and using that gas in the furnace itself?

Mr. Taylor:

I think so.

Mr. McKenna:

We cannot afford to waste CO.

Mr. F. W. Frerichs:

Are any such furnaces in active operation? I read in a recent number of the Electrochemische Zeitschrift that in Germany furnaces of this kind are already in operation. There is one 4-ton furnace mentioned, and another of 16 tons capacity per day. I would like to know if there has been anything of that kind done here.

Mr. Taylor:

The principal work has been done in California in the reduction of iron ore, and in Canada. The Canadian Government has fostered this work very much, but their methods have been methods of experimentation in the main, and most of them of such a character as not to admit of exceedingly large construction. The nearest that has been attained to that is work that has been done in Norway, where a stack furnace has been produced which admits of larger construction, and the Canadian Government is about to undertake work along that line in the very near future. I think that is the only furnace the principles of which are capable of being put into very large construction.

Mr. J. C. Olsen:

I should like to ask with reference to the lining, do you use any different lining here than in the ordinary furnace?

Mr. Taylor:

In the bisulphide furnace I use ordinary fire-brick for the lining, although some of the channels, back, were lined with common clay brick, that is, building brick. I do not think that in an electric furnace on this plan for smelting iron, anything better than fire-brick would be required for the lining. Undoubtedly, as we find in this furnace, these arches (after we have run some time these electrodes are burned clear back to the iron) have to be repaired. These are the only repairs we have to make. Sometimes we have run longer than we needed to, so that the first casing has been sacrificed. When we run them back as far as that, then the lining right around this has a harder time of it, but if we were careful not to burn the electrode back too far into the arch it would receive very much less wear. Of course, the

temperature of a furnace for smelting iron would be higher than that of the bisulphide furnace, but we do not anticipate any trouble in using fire-brick in lining furnaces for the smelting of iron.

Mr. Olsen:

Are the arches of the same material?

Mr. Taylor: Yes.

Mr. A. C. Langmuir:

Do you put in just sufficient carbon to combine with the oxygen of the iron, and rely upon the limestone to furnish the carbon dioxide necessary, which later on decomposes to CO? Also is the purity of the pig iron greater than that from the blast furnace?

Mr. Taylor:

The probabilities are that there might sometimes be an accumulation of carbon in excess of what was necessary to smelt the iron, and I should have mentioned that provision is made through these screws to introduce air, so that we can, in case of an excess of carbon getting in our way, throw in a current of air and burn it up. Ordinarily speaking, there is expected to be fully as much carbon in the furnace as is required by the reduction. We are governed by experience, and if we find we have too much, we burn it out, if not enough, we put it in more rapidly. We can also put some carbon in with the ore if we choose to. Upon applying heat the first action would be that any oxygen within reach of the carbon would necessarily be converted into CO, and that, when it got a chance at the iron ore, would absorb some oxygen from it and be converted into carbonic acid. Then if the CO_2 came in contact again with the incandescent carbon it would be reduced again to CO.

Mr. F. W. Frerichs:

The 16-ton furnace to which I referred a little while ago was described in a German publication, and the article was to be continued. I understood from the first part that the furnace was to be used for the manufacture of high-grade tool steel. Can you give us any information as to the quality of the iron made in such a furnace, and whether it is made directly from the ore, or whether they in some way introduce wrought iron or low-carbon steel in order to obtain a finished product?

Mr. Taylor:

As a matter of fact all the experience that has been had with the electric furnace goes to show that with the same quality of ores and flux a better quality of iron will be produced than by means of the blast furnace. I think there is no question but that a superior quality of metal is obtained.

Mr. McKenna:

At the risk of being out of order, I would like to ask one more question. I should like to know whether Mr. Taylor does not consider that the making of steel and the reduction of iron ore to pig iron are going to be always distinct in electric iron smelting.

Mr. Taylor:

Yes, sir, I think so. The idea of this furnace is more especially to make pig iron. The excess of carbon that I figure on will probably lead to a carbonized iron, rather than the low-carbon product required for steel. Of couse, that cannot be determined until the work is done.

WATERWAYS AND WATER POWER

By EDWARD R. TAYLOR

Read at Philadelphia Meeting, Dec. 10, 1909

There is much said to-day concerning water powers. It is going to make a great difference how they are developed. Every business man is interested in commerce and transportation, while few have any interest in water powers—and there is great danger that those interests will be overlooked.

Waterways must be treated on broad lines, and co-ordinated with other interests. What a person or corporation or a State may do with a given stream may block a more comprehensive or national development.

The barge canal now building, with a fall of 564 feet from Lake Erie to the Hudson River, could be made down hill all the way, and the key to the water-power situation in New York State, and capable of producing water power worth five hundred million dollars, is being built without reference to water power even for the hauling of boats through the canal—in this age of electrical and other opportunity. The water that can develop one horse-power at Niagara Falls is capable of generating four horse-power through such a canal constructed for power and navigation purposes, and in a few years the entire cost be repaid from the sale of power.

Illinois has started to build such a navigation and power canal, and estimates that the entire cost will be repaid the State for power alone in only seventeen years. Just now that fine enterprise is being blocked by a single water-power interest on the Des Plaines River. Such examples ought to teach us that in doing a truly great thing it is easy to overlook a greater.

Most of our people live in the lower parts of the country and do not realize the immense capacity and value of the hill country for the storage of water for power and navigation purposes, and the lessening of damages by flood and erosion, and advocate dredging

for all they want, instead of dredging some and in addition storing water in the hill country.

I need not point out the future demands for power by the chemist, before this body of Chemical Engineers, or make apology for this brief on so important a subject. Every such organization as ours should put its shoulder to the wheel of this important interest.

(Mr. Taylor then read a tentative resolution, addressed to the Conservation Congress then sitting in Washington, upon the subject of the Conservation of Water Power.)

Pres. SADTLER:

This is a very important matter. The members have all read a great deal about the great and critical importance of this looking after the conservation of water power and other natural resources. It is a very live question, which is now very much in evidence in the popular magazines, and is being discussed by this "Conservation" Congress at Washington. Mr. Taylor has been connected with the work and has made several reports. I am very glad that he has presented the matter to us here. Chemical engineers ought to interest themselves in such questions, and make their influence felt. I would be very glad to have this matter represented as coming from this Institute.

Mr. MCKENNA:

I was going to remark that adverse comments upon such improvements, where they are based on a single large stream with a large watershed, have usually arisen from unfavorable results of similar large hydraulic improvements in the past. But analysis of the causes of disaster has usually shown them to lie in politics, in the wastefulness of the engineers, in bad engineering principles, or in fundamental mistakes. Another reason sometimes, I think, at the bottom of unfavorable comments on large projects, is the lack of knowledge as to what will be the income from the power plant, and this is the point at which the chemical engineer in the future will be relied upon for more light and for fuller information, because power plants can be established in the heights and backwoods where there will be no consumer like a trolley company or a lighting company, or city, but where, perhaps, due to juxtaposition of some valuable minerals, the chemical engineer can find a profitable use for the current, and the price he can

afford to pay for using it for his reactions is something that the hydraulic engineers, or engineers considering the economics of the proposition, would like to know. The field in which the chemical engineer can assist will be in the giving of exact information by such experienced men as Mr. Taylor.

Mr. J. C. Olsen:

It seems to me that this is an excellent resolution to pass, but it might be desirable to consider the form of this resolution rather carefully and of any specific recommendation which we might wish to make, and I should like to move that a committee of three be appointed to consider this resolution carefully, and possibly to make some desirable additions, and report on Friday, after having carefully considered its form and substance, and whether further additions can be made to strengthen it.

Mr. Taylor:

I would be very glad if that could be done at a very early time. I thought this would go to your Committee on Resolutions, and that thus I should be helped in the matter, and not have it in the form of just one man's thought. But the congress in Washington adjourns on Friday, and it is very desirable to have it before them before that time.

Mr. Olsen:

I would amend then that the Committee report this afternoon.

Mr. McKenna:

If the Secretary will read the resolution, paragraph by paragraph, we can close the matter within ten minutes.

(Mr. Taylor's resolution was then read over by Mr. Olsen.)

President Sadtler:

We cannot attempt to cover in that brief series of resolutions all the points and illustrations which would go to urge such action. Mr. Taylor has referred, for instance, to the exposure of the State of Illinois to the sewage of Chicago (?). Illustrations of that kind will, no doubt, be brought out when they have their meeting, and simply act as so many reasons why these resolutions have force. I think if the wording of the present resolution is slightly amended, it covers the thing as far as we can do it, unless we had a committee get together information and put it in the form of resolutions, and we cannot possibly do that.

Mr. Frerichs:

I think that the thing of principal importance is that the resolution be sent in quickly. I think it would be advisable to send it by telegram directed to the president of the congress, and believe that in that way it will be brought to the notice of the convention much more forcibly than if it is received on the last day.

Mr. Olsen:

It would reach there to-morrow if we send it to-day.

Mr. Grosvenor:

Would it differentiate the resolution of this Institute perhaps from that of other societies if we avoid mentioning specifically our own profession, taking perhaps the broader attitude, and simply requesting that experts in all the associated lines be called upon for their assistance? The action would be perfectly obvious and a little more dignified.

Mr. McKenna:

I withdraw my objection, and consider that it should go to a committee, and be put through so that it can be mailed this evening.

Motion seconded and passed.

Committee appointed by President Sadtler: Dr. McKenna, Dr. Frerichs, Mr. Taylor.

The resolution as passed will be found on page 28.

INDEX

PAGE

Acid egg, an automatic 201
Activities suggested for the Institute 38
Address of welcome, by Herman A. Metz 1
by Prof. Irving W. Fay 3
to Philadelphia by Mr. Gleason 15
Addresses and Papers 64
Advantages of multiple-effect distillation of glycerine and other products .. 274
Alexander, Jerome, Colloids and the ultra-microscope 210
America, Chemical industries of, by Prof. Chas. E. Munroe 84
Amendment to Constitution, with reference to ex-presidents 33
with reference to initiation fee 36
proposed by the Membership Committee 19, 31
Andrews, Launcelot W., on the permanence and acidity of hydrogen peroxide solutions 238
Annual Meeting, second 15
Automatic acid egg 201
Bement, A., Chemical composition of Illinois coal and relation of heating value to composition 175
Heat efficiency of smokeless combustion and heat-absorbing capacity of boilers 156
Booth, Wm. M., Commercial extraction of grease and oils 248
Treasurer's reports by 7, 24
Brierly, John R., Some experiments on the case-hardening of steel by gases 194
By-Laws 54
Case-hardening of steel by gases, Some experiments on 194
Cement, A method of clay control for the manufacture of 204
Centering of great industries in the New York metropolitan district, Charles F. McKenna 65
Chemical composition of Illinois coal and relation of heating value to composition 175

PAGE

Chemical Engineering Education, Committee on 56
Discussion concerning 25
Report of committee on 24
Chemical industries of America, by Prof. Chas. E. Munroe 84
Colloids and the ultra-microscope 210
Commercial, extraction of grease and oils 248
Museum of Philadelphia, Facilities of 45
Committee, on Chemical engineering education 56
on Finance 56
on Medal 56
on Meetings 56
on Meetings, instructed to select place for holding meetings 35
on Membership 56
on Publications 55
Committees and officers for 1910 55
Conservation, and the chemical engineer 105
of national resources, Resolution with reference to 28
Constitution 49
Creosote oil from water-gas tar 177
Dean, J. G., A method of clay control for the manufacture of cement 204
Dinner at Philadelphia meeting 47
Efficiency limits in the power-gas producer 115
Electric furnace for the smelting of iron ore 280
Ennis, Prof. Wm. D., Efficiency limits in the power-gas producer..... 115
Excursions, at Brooklyn meeting 13
at Philadelphia meeting 45
Ex-Presidents, Amendment to Constitution with reference to 33
Fay, Prof. Irving W., Address of welcome by 2
Finance Committee 56
First Semi-Annual Meeting 1
Frerichs, Dr. F. W., elected vice-president to succeed Dr. Hunicke 36
Fuels, Utilization of low-grade, in the United States 140
Gleason, Address of welcome to Philadelphia by..... 15
Glycerine refining in multiple-effect stills 261
Grease and oils, Commerical extraction of 248
Heat efficiency of smokeless combustion and heat-absorbing capacity of boilers 156
Hunicke, Dr. H. A., portrait of 5
Resolutions on the death of 5
Hydrogen peroxide solutions, Permanence and acidity of 238
Test for permanence of 244
Illinois coal, Chemical composition of, and relation of heating value of, to composition 175

PAGE

India rubber, waste, Utilization of 229
Initiation fee, proposed amendment to Constitution with reference to..... 36
Institute, Activities suggested for..... 38
medal, Discussion with reference to 30
Iron ore, Electric furnace for the smelting of 280
Junior membership, Amendment to the Constitution, providing for 19
Discussion concerning..... 20, 31
Langmuir, A. C., Report of membership committee by 18
The advantages of the multiple-effect distillation of glycerine and other products..... 274
List of members for 1910 57
McKenna, Charles F., The centering of great industries in the New York metropolitan district 65
Meade, Richard K., An automatic acid egg..... 201
Medal, Committee on 56
Discussion with reference to the establishment of 30
Meetings, Committee on 56
Members, List of 57
Membership Committee 56
Reports of 6, 18
Method of clay control for the manufacture of cement 204
Metz, Herman A., Address of welcome by 1
Multiple-effect stills, Glycerine refining in..... 261
Advantages of 274
Munroe, Prof. Chas. E., Chemical industries of America 84
New York metropolitan district, Centering of great industries in, by Charles F. McKenna..... 65
Officers and committees for 1910..... 55
Olsen, John C., Some experiments on the case-hardening of steel by gases..... 194
Permanence and acidity of hydrogen peroxide solutions 238
Philadelphia meeting, Dinner at 47
Excursions at 45
Second annual meeting held at 15
Polytechnic Institute of Brooklyn, First semi-annual meeting held at... 1
Power-gas producer, Efficiency limits of 115
Publications, Committee on 55
Report of, Committee on chemical engineering education 24
Membership Committee 18
Resolutions on the death of Dr. H. A. Hunicke 5
Sadtler, Samuel P., Conservation and the chemical engineer 105
Creosote oil from water-gas tar 177
Second Annual Meeting 15

PAGE

Semi-Annual Meeting 1
Sharples, Stephen P., The utilization of waste india rubber 229
Smokeless combustion, Heat efficiency of 156
Some experiments on the case-hardening of steel by gases 194
Taylor, Edward R., Electric furnace for the smelting of iron ore..... 280
Waterways and water power 300
Treasurer's reports 7, 24
Ultra-microscope, The, and colloids 210
Utilization of, low-grade fuels in the United States..... 140
waste india rubber 229
Water-gas tar, Creosote oil from 177
Waterways and water power..... 300
Weiffenback, John S., Some experiments on the case-hardening of steel by gases 194
Wood, F. J., Glycerine refining in multiple-effect still 261
Zwingenberger, Dr. O. K., Utilization of low-grade fuels in the United States 140

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